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RESEARCH MEMORANDUM

LONG~UDINAL STABI~Y C~RACTE~TICS AT MACH NUMBERS UP TO 0.92 OF A ~G-BODY-TAIL COMB~ATION HA~G A ~G WITH 45° OF SWEEPBACK AND A TML ~ V~OUS VERTICAL POSITIONS

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON

J=wy 28, 1955

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RESEARCH MEMORANDUM

LONGITUDINAL ST~LI~ CHARAC=STICS AT MACH mERS ~ TO O. ~ OF A WING-BODY-TAIL COMBINATION HA~G A WING WITH 45° OF SWEEPBACK AND A T~L IN V~OUS VERTICAL POSITTONS

By Jack D. Stephenson, Angelo Bandettini,
and Ralph Selan

SUMMARY

Wind-tunnel tests were conducted at Mach numbers from 0.25 to 0.92 to measure the static M@tudind stability characteristics of a semispan wing-fuselage-tail model having a w- with 45° of sweepback. The wing had an aspect ratio of 5.5 and had N~A 64$_{AOI0}$ sections normal to the quarter-chord line. A plane, unswept, horizontal tail of aspect ratio 4 was mounted in four different vertical positions vax from 12.7-percent semispan below the wing chord plane extended to 25.5-percent semispan above the chord plane extended.

The center of pressure of the wing-fuselage combination moved forward as the wing began to stall, and a tall in the higher positions produced additional stalling moments due to high effective downwash. The bss of tail contribution due to the downwash was delayed to higher angles of attack when the tail was lowered to the wing chord plane extended.

The addition of kading-edge fences or of leading-edge chord -ens sions reduced the forward center-of-pressure movement of the wing-fusela,& combination and the losses in tail contribution that occurred when the wing stalled.

INTRomcmol!?

Existing results of aerodpic studies of w-s similar in plan form to the one employed on the model which is the subject of this report tidi-cate that the combination of plan form and section selected for this model wotid have high aerodynamic efficiency at high subsonic Mach numbers (refs. land 2). The tests reported herein were undertaken to obtati fur-ther information applicable to a complete airplane configuration suitable for superior lo~-rqe performance at high subsonic speeds. Previous tests of wings of this genera p- form indicate that at high lift coef-ficients they are subject to severe longitudinal instability as a result of an extreme forward movement of the center of pressure which results from separation of the flow at the w- tips.

[redacted]

Tests such as those reported in references 3 and 4 of wing-body-tail combinations have shown that the contribution of the tail to the stability is of a regular nature and can generally be predicted when the wing is unstalled. However, when separation occurs on the wing, it has been observed that high downwash may occur at certain possible tail locations, causing more severe longitudinal instabi~ty than that due to the wing and fuselage. Other tail locations have been observed where the reductions in stability of the wing-fuselage combinations are partially or completely compensated for by simultaneous increases h the contribution of the tail to stability (see refs. 5 and 6).

Reference 2, which preaefits""data "fr~m tests of a model having the wing used in the tests described in the present report and havtig-a similar fuselage, indicates that the model was not subject to-large adverse effects of compressibility on minimum drag or on maximum lift-drag ratio up to high subsonic Mach numbers. The tests re~rted herein were intended to ascertain to what degree the severe static longitudinal instability of the ting-fuselage combination might be a~oided In the case of a model with a horizontal tail. The means of avoiding or reducfng this instability included varying the vertical position of the horizontal tail and adding fences and chord extensions to the wing.

A continuing part of this program is-aimed at obtaining more detai~d information indicating local flow characteristitis in the region of the tail of this model, which it is hoped will afford a basis for improved methods of estimating *downwash* behind swept wings.

NOTATION

at	lift-curve slope of the isolated tail
%+h	lift-curve slope of the wing-fuselage combination
%b+t	lift-curve slope of the wing-fuse-e-tail combination
b	wing span
c	local wing chord para~el to the plane of s~etry
E	wing mean aero~amfc chord, J b l ' . 2 ~, 0 J - * O
CD	drag coefficient, $\frac{\text{drag}}{q\ \sim}$
CL	lift coefficient, $\frac{\text{lift}}{q\ \%}$

C_m pitching-mogent coefficient about the quarter-chord point of the wing mean aerodynamic chord, $\frac{\text{pitching moment}}{\sim\ \%}$

i_t incidence of the horizontal tail measured from the body center tie, deg

l length of the body

l_t tail length, distance from the qu-er-chord point of the @mean aerodynamic chord to the qmrter-chord point of the horizontal-tail mean aerodynamic chord

M free-stream Mach nuuiber

q free-stream d-it pressure

q_t effective dynsmic pressure at the tail .

R Reynolds number based on wing mean aerodynamic chord

r local raifius of body

r_o maximum radius of body

S_w area of basic semispan wing

S_t area of semispan tail

V_t horizontal-tail volume, $\frac{\%Zt}{S_w\bar{c}}$

x longitudin~ distance

y lateral distance from plane of symmetry

α mgle of attack, deg

α_t tail angle of attack, deg

ϵ downwash angle, deg

η tail efficiency

MOD= AND APPARATUS

Figure 1 is a sketch of the model. The model consisted of a semispan wing, ~selage, -d horizontal tail. The wing was constructed of solid aluminum alloy-and ha 45° of sweepback at the quarter-chord line, an aspect ratio of 5.50, a taper ratio of 0.53 and was without twist. me airfoil section normal to the quarter-chord line was the NWA 64A010.

The fuselage, a half-body of revolution of fineness ratio 12.5, waa of cast aluminm mounted on a steel spar. me center line of the fuselage coincided with the wing-root chord line, and the quarter-chord position of the wing mean aerod~amic chord was alined with the midpoint of the body length.

The horizontal tail surface was mounted in positions representative of possible locations of the tail on a long-range airplane. The tail volume is also believed to have been typic~ of such an airplane. The geometry of the tail surface was selected.because its aerodynamic characteristics indicated that it would be favorable for measuring effective downwash at the tail location. A similar surface was shown in reference 7 to be free from large or erratic compressibility effects tioughout the Mach number range of the model tests and to have a lift curve that was linear tithin a wide angle-of-attack range. The tail surface represented an all-movable stabilizer having zero sweep of the midchord line, an aspect ratio of 4.0, a taper ratio of 0.5, and NMA 63AOOb sections. me tail area was 24.8 percent of the wing area and the quarter-chord point of the tail mean aerodynamic chord was 2.06 behind the quarter-chord point of the tiag mean aerodynamic chord. Provision was retie to mount the horizontal tail at four vetial. positione, as fo~ows: (a) a low position)l~.7 percent of.the wtig semispan below the wing chord plane efiended; center position in the wing chord plane extended; (c) a medium high position 12.7-percent sefispan above the wing chord plane extended; and (d) a high position 25.5-percent tiemtspan above the tig chord plane extended. The tail surface was supported in the three positions away from the fuselage center line by means of steel pylons. The Junctures between the stabilizer and pylon were covered with a woud fairing as sho~ ti figure 2(a). When the tail was mounted below the *fuselage,* an additional fairing was installed over the pylon surface between the juncture fairing and the fuselage (fig. 2(b)) h an effort to reduce interference at high angles of attack.

The fences shown in figure l(b) were mounted on the wing during portions of the test at one or more of the fo~wing spanwise stations: 0.44b/2, 0.57b/2, 0.69b/2, and o.82b/2. Figure 2(c) is a photograph of one combination of the fences. Provision was made for testtig the fences with the rearward 70 percent or D percent removed. ~adfng-edge chord extensions were also tistalled on the outer portion of the wing during part of the test. These extensions (shown in figs. l(b) and 2(d)) increased the local chord normal to the quarter-chord line by 15 percent and increased the streamwise chord by 17 percent. The inner ends of the chord extensions, which were located as indicated in figure l(b), were plane surfaces parallel to the model plane of s~etry. The chord-extension section was similar to the forward part of the original section, except for a reduced thickness ratio and nose radius, and was faired into the basic wing *section at* its maximum thickness. Coordinates of the chord extensions in sections normal to the quarter-chord line of the orfginal wing are *given* in table I. me wing area of the model ws increased by 8 percent when the largest chord extension was installed.

Additional "geometric data are listed in table ~ for the various model components.

a m

~erimental studies were conducted to determine the static tingi-tudinal stability characteristics of the model without the tail and with the tail mounted at each of the four positions indicated in figure 1. With the tail at the fuselage center line and 12.7-percent semispan above the center ~, its incidence *was* varied from 0° to -5°.

Effects of various fence installations upon the characteristics of the wing-fusekge combination were measured in a limited series of tests and one fence configuration was s~ected for more detaibd stability studies. The effects of kading-edge chord tiensions upon the longitu-dinal stability of the model were -so investigated.

Measurements were made of I-ift, drag, md pitc~ moments at Mach numbers from 0.5 to 0.92 at a Reynolds number of 2,000,000. At a Mach number of 0.25, data were also obtained at a Reynolds number of 10,000,~0.

CO=TIONS TO DATA

The data have been correctid for constriction effects due to the presence af the tunnel walls, for tunnel-w~ interfe=nce effects origi-nating from lift ~n the model, and for the drag tares caused bY aerodw=ic forces on the exposed portion of the turntable on which the model was mounted.

The dynamic pressure and the Mach number were co-netted for constric-tion effects due to the presence of the tunnel walls by the methods of *reference* 8. The corrected and uncorrected Mach numbers =d the ratio of corrected to uncorrected dynamic pressure are presented in table III(a). The correction to the drag coefficient for the effect of the pressure gradient due to the wake was esttiated and found to be negligible.

Corrections for the effects of tunnel-wall interference due to mode 1 lift were calculated by the method of reference 9. The corrections (which were added t~ the data) were as fo~ws:

Am= $K_= C!_L$ $\quad$ $A C_m = K_2 C_L$ $\quad$ Model without tail

ACD = $0.0053\ C_L^2$ $\quad$ $A C_m =$ &CL $\quad$ Model with tail

The values of K_1, K_2, and K_S are shown h table III(b) as functions of Mach number.

Since the turntable upon which the model Ms mounted was directly connected to the balance system, a tare correction to the drag was necea-Sary. The magriitude of this correction was calculated by multiplying the forces onthe turntable with the tiodel iernoved~ the $ragt$on of the area ., of the turntable sti~ exposed to-the air stream after installation of the mode 1. The tare corrections, converted to tare drag coefficients based on wing area, were subtracted from the measured drag coefficients and are presented in table ~(c). No attempt has been made to evalwte tares due to interference between the model and the turntable or to compensate for the tunnel-floor bound- layer, which at the turntable had a displacement thicdess of one-half ~.

RESULTS ~ DIS~SSION

Basic Model

The lift, drag, an"d moment characteristics of the wing-fuselage combination are presented in figures 3 and 4. Thef3e data are practically identical to those measured on a similar wing-body combination and reported in reference 2. Throu@out the test r-e of Rewelds numbers and Mach numbers and at lift. co~fficients greater–than abbut 0.6, the center of pressure of the wing-body combtiation moved forward rapidly with increasing angle of attack. As is well known, this behavior is a result of flow sep-aration beginning at the wingtip and progressing inward with increasing angle of attack and is characteristic of wings of this general plan form. In addition to the data for the wing-fuselage cotiination-}_-data are pre-sented for the modeI with the three tail-mounting pylons and fairings, which, except for ticreasing slightly the level of.the drag data, had only minor eftects. Small differences in pitching moments for various tail-mounting pylons can be attributed to the fact that the characteristics at the stall were somewhat erratic and not repeatable.

Figures 5 and 6 show the effects of adding the horizontal-tail surface in various vertical poSitionS. The pitching-moment data referred to the wing quarter-chord point indicate a considerable static margin for the tigle-of-attack range where the lift curve remained linear. At the higher angles of attack, large and abrupt movements of the center of pressure occurred. These movements were greatest when the tail was in the highest position and decreased progressively as the tail was lowered. A detailed comparison of the pitching moments of the model with and without the tail (figs. 3 through 6) indicates that when the tailwas 12.7-percent semispan below. the fuseLage, it contributed to.the stability throughout the angle-of-attack range, whereas for higher tail locations, when ting stalling occurred, the tail contributed a Towerful positive pitching moment."

me decreased static longitudinal stability near zero lift for the model tith the tail at the fuselage center tie is an indication of the effect of the wing *e. me data show that the pitching moment at zero lift varied with tail height, indicating a local flow at the tail directed inward toward the fuselage =is.

Effect of Fences

The effect of the location of ~-chord fences was investigated at two Mach numbers by insta~ the fences in several combinations at one or more of the fo~wing stations: 0.44b/2, o.57b/2, o.69b/2, and o.82b/2. The Et and moment characteristics of the model without the tail (fig. 7(a)) indicate that at a Wch number of O.= a single fence at 44-percent semispan increased the lift coefficients at which large forward center-of-pressure mvements occurred and reduced the magnitude of these movements prior to the attainment of maximum lift. The least variation of center of pressure with lift coefficient restited when two fences were used, one at 44-percent and one at 69-percent semispan. None of the fence combinations provided any substantial i~rovements at a Mach number of O.9. It was ~cted that some insight into the origin of the improved stability due to the fences might be afforded if the chordwise extent of the fences were vmied. Results of tests with two fences (at 44-percent and 69-percent semispan) having the after ~ percent and the after 50 percent of the fences removed are presented in fi~e 7(b). me data show that fences extending over only the forward ~ percent of the chord were almost as effective as any af the longer chord fences, indicating that the effects of separation on this wing were most strongly influenced by the flow near the leading e~e. me full-chord fences resulted in slightly higher values for the lift coefficient at which the center of pressure moved forward. On the basis of these kited tests of the model without the tail, the full-chord fences at O.~ and 0.69 semispan were selected to be tested in more detail.

me lift, drag, and moment characteristics of the model without the tail and with full-chord fences at 0.44 and 0.69 semispan are shown in figure 8 at Mach numbers from 0.25 to 0.92 and a ReynoHs number of 2,000,000. At all these,Mach numbers the fences reduced the forward center-of-pressure movement accompanying stalling of the wing (prior to maximum lift)” and at Mach numbers up to O.@ substantially increased the ltit coefficient at which instability occurred. me addition of the fences had very slight effect on the minimum drag and reduced the drag at moderate and high lift cufficients. At a Mach number of 0:92 there was some drag penalty due to the addition af fences.

Figure 9 shows the longitudinal characteristics of the model with fences and the various tail pylons at a Re~olds ntier of 10,000,~ and a Mach number of O.=. Similar *data* for the Mach number range 0.25 to 0.92

at a Reynolds number" of 2,000, WO are pre-sefiked 'in f Igure ZO. Comparis&" """ with the same t~e of data for the model without fences (figs. 3 and 4) indicates that the incansi~tencies in the pitching-moment characteristics at the stall were somewhat ,reduced by the addition csf fences.

Data for the model with fences and tith the tail in various vertical positions are presented in *figures 11* and 12 for Reynolds numbers of 10,000,000 and 2,000,0~, respective@. "~ith""ih=~ail in the high posi-" ' tion, lo~itudinal instability occurred at angles of attack where the wing *was* partially stalbd (as indicated by decreased lift-curve elopes). hwering the tail decreased the magnitude of tie instability and increased the angle of attack where it first occurred. With the tail in the chord plane extended, there were r&latively small. variatio~s with lift coefficient of the center-of-pressure location, and the pitchtig-moment curves were considerably more ltiear than those for the niodel without fences. The improved stability for the higher tail positions was partly due to the effect mentioned previous~ of the fences on the stability of the wing-body combination. A detailed exminat~on of the pitching moments of the model with fences both with and without the tail (figs. 9 through 12) haa indicated that the tail did not contribute the large positive pftching moments which were observed for the model without fences, when the wing was partially stalled. Although the model was-generafiy stable-at maximfi """ lift (in those cases when it was attatied), with the tail in the two lower positions there was an abnpt change in pitching m~ent at high angles of attack prior to maximum lift. ~is is believed to have been due to stalling of the tail. Such sta~ing probably does not represent a flight problem for an airplane Wth a center-of-gravity location that would normally be ~mployed because of the decrease in tail inctience" that "would be necessary for longitudinal balance in f~ght at these lift coefficients.

Effects of Chord Hensions

me lift and moment data measured at a Mach number of O.= and a Reynolds ntier of 2,000,000 are presented in fi~re 13 for" the wing-fuselage model with &ad extensions of various spans. The greatest improvement in linearity of the pitching-moment data resulted when the leading-edge discontinuity was at the innermost location. The addition of a fence at this disconttiity produced no improvement. The effects of increased Mach nwber on the characteristics of the wing-fuselage combi~-tion with the two longest span chord etiensions are shoti in figure 14. The pitching-moment characteristics of the wing-fuselage model with chord extensions were similar to the characteristics of the model with fences. At Mach numbers up to 0.85, there were sub.staritial ticreases in the lift: coefficients where large center-of-presstie m~ents *occurred,* but at Mach numbers of 0.90 and 0.92, only slight increases in the lift coefficients are evident. Although the increased wing area due to adding the chord extensions ticfiased the lift propotiionately, this effect accounts for less tha a sixth of the measured increase in the lift coefficient at which longitudinal instability occurred at the lower speeds.

b order to determine whether the downwash at the tail would be significantly influenced by the span of the chord extension, tests were conducted with two of the more promising chord *nsfons, one extend= from 44-percent semispan to the wing tip and the other from 57-percent semispan to the tip. As shown in fi~res 15 and 16, with the tail in the wing chord p-e -nded, large forward movements of the center of pressure were avoided ahost up to the wing m=imum lift when either of these chord extensions was emplo~d. Raising the tail to the medium position (O. 127b/2) had adverse effects u~n the stability, particul-arly with the shorter span chord etiension. The addition of the longer span chord extension resulted in stability characteristics of the complete model quite similar to those of the model with fences.. Because there was no clear superiority in the characteristics of the model with chord extensions over those of the model with fences, this modification was not studied in more detail. The possibi~ty exists that one wing leading-edge modification may have some advantage in drag **over** the other modifications, but it is believed that the tests reported herein are ticonclusive in this respect because the method of attaching the fences (fig. 2(c)) is certainly not optimum from the drag standpoint and because the basic-wing drag may have varied when the surface conditions were not sufficiently we~ duplicated each time the chord extensions were installed or removed.

Effectiveness of the ~il as an U-Movable Control

Figures 17 and 18 present data showing the effects of varying the tail incidence on the model without fences or chord extensions. At a Reynolds number of 10,000,000 (and Mach n@er of O.=) figure 17 shows that varying the tail incidence from 0° to -5° was effective in varying the pitching moment at all angles of attack below =imum lift. ~roughout the Mch number range at a ReWolds number of 2Y~YOoo (fig. 18)> the stabilizer provided effective control until the effects of wing stalling upon the stability became *large.*

With two full-chord fences on the model, the data pres~ted ~ figures 19 and 20 indicate that the stabi~zer was effective until the wing st~ed, but the effectiveness at the stall was erratic in some instances. Abrupt forward movements of the center of pressure occurred near **maximum** lift at some Mach numbers, but the etude-of such movements was sma~ when the tail incidence was -5°.

Characteristics at k Lift Coefficients

The slope of the Ht and pitching-moment *curves* and the variation of pitching-moment coefficient with stabilizer angle derived from data in the preceding figures are shown in fi~re 21. ~is figure shows ~m/~L of the model without the tail at a lift coefficient of 0.1. mis lift coefficient was selected to indicate the slope of" the moment curve at low angles of attack and still avoid a discontinuity in the slope that characterized the data near zero lift at the higher Mach numbers with the tail off. Adding the fences caused the rea~d movement of "the aerodynamic center of.the wing-fuselage combination at low angles of attack to occur at a lower Mach number. Data showing dC~dCL of the complete model indicate that raising the tail from the fuse~e center line to the medium (O. 127b/2) position tireased the. static. stability at zero lift. Adding fences produced no consistent-effect on the stability of the complete model at zero lift. The stabilizer effectiveness U#dit at zero angle of attack shown in fi~re 21 as a function of Mach number indicates that increasing Mach nmber produced gener~y higher effectiveness, particularly when the tail was in the medium high location.

Tail Contribution to Stability

The force and pitching-moment data for the model with the medium and center-line tail locations (figs. 17 through 20) have been used to estimate the effective downwash angles sho~ in fi~es 'w and 23 as functions of angle of attack. (In order to estimate the downwash at high ~les of attack, it was necess"a~ to assume that the stabilizer effectiveness data could be extrapolated to include negative angles of incidence of the tail that were beyond the range of the e~erimental data.]

In figure 22 and at the top of figure 23 the effective downwash data at a Mach number of 0.25 are shown at two Reynolds numbers> _l0,000,~ and 2,000,000, respectively. Ai both "Refiolds n~bers, ~he slopes of the downwash curves for the model without fences increased sharply at anghs of attack slightly exceeding those where wing-body instability ocmrred. At all of. the Mach numbers of the test (at a Reynolds *nber* of 2,000,000) the slope of the d~tish curves increased with angle of attack, but, when the tail was lowered to the center line, this increase was-delayed to higher angles of attack (see fig. 23). The effects of addinE fences are also shown in figures 22 and 23: tie most significant effect was to decrease the downwash at the higher angles of attack, particularly in the region of the medium tail.

Force and pitching-moment data for the model with and without the tail, and force data for the isolated tail have been used to calculate the contribution of the horizontal tail to the longitudinal stabi~ty, as expressed in the fo~wing formula.

$$\left(\frac{dC_m}{dC_L}\right)_t \doteq -V_t \frac{a_t}{a_{w+b}}\left[\eta\frac{q_t}{q}\left(1-\frac{d\epsilon}{d\alpha}\right)+\alpha_t\frac{\partial\left(\eta\frac{q_t}{q}\right)}{\partial\alpha}\right]$$

~is e~ression for the tail stability parameter (dC~dCL) t, wht~ is the variation of pitching-moment coefficient due to the tail with lift coefficient of the wing-fuselage cotiination, affords a useful indication of the way the separate factors affect the tail contribution to the pitching moment of the model. This parsmeter is rehted to the increment due to the tail in the stabi~ty of the complete model by the expression

$$\left(\frac{dC_{m_t}}{dC_L}\right)_{w+b+t} = \frac{a_{w+b}}{a_{w+b+t}}\left(\frac{dC_m}{dC_L}\right)_t$$

me terms in the expression for the tail stability parametir were evaluated as follows: me lift-curve slope of the isolated tail ~ estkted from references 7 and 10 was measured at the average effective tail angle of attack as indicated by the effective downwash data. It was assumed that the Mach ntier at the tail was the s- as the free-stream Mach number. The Mt-curve slow of the ~-fUS~age combination ~+b was measured from data presented in figures 3, 4, 9, and 10. me product of the tail efficiency and the d-it pressure at the tail q(~/q) was computed from the relat~on ~-t q-- ~ $\frac{dC\sim dit}{V_t a_t}$ where d~dit is the stabilizer effectiveness measured at constant model angle of attack. In calculating the tail contribution, the term ~ —was neglected.

The variations of the tail contribution to the stabi~ty and the factors making up this contribution are shown in figure 24 for a Reynolds number of 10,000,000 and a Mach nmber of O.=, and in figure ~ for a Reynolds n-er of 2,000,000 and Mach ntmibers of 0.6, 0.8, and 0.9. Mthough the factor a~~+h and the tail-efficiency and d-it-pressure factors indicated sizable variations with me of attack for all tie conditions shown, they did not appear to be of major importance in determining the effect of ths vertical tication of the tail. A c~arison of the variations ~th angle of attack of the downwash factor (1 - de/din) and the tail stabi~ty parameter $(dC!\#dCL)_t$ indicates that practically all of the significant characteristics of the *latter can* be traced to variations in downwash. At Wch numbers at least up to 0.9, rapid increase of effectim downwash at the tail with increasing angle of attack resulted in decreased contribution of the tail to stability. When the tail was lowered from the medium to the center position, this decrease was dela~d to higher angles.

The effects of ~ding fence; to the model were to reduce or eliminate large erratic variations of $(d\sim dCL)_t$ at high angles of attack and under some of the test conditions to eliminate a kss of tail contribution that occurred as the wing first began to stall. This 1oBS in tail contribution for the model without fences is the most noticeable in the data for the *medium* tail height and was sti~ present to a lesser degree *when fences were* installed. At each of the test conditions shown, when such a loss occurred, it was diminished or avoided by lower% the ta~~ to the model center line.

The large variations that are a~arent in the factor (1 - de/da) may give rise to speculattin as to the accuracy of such data, in view of the difficulty in calculating effective downwash from data in which the pitching moments are erratic. Although large and abrupt changes in the pitching-moment coefficient were measured when stalling of the ting occurred, it is betived that by careful examinati~n of the moment data it has been possible to determine effective downwash angles that are at least qualitatively reliable and do not *include i~rtant* effects of dispersion or other inaccuracies.

Figure 25 includes some values of q(qt/q) which appear to be too high, exceeding unity at Mach numbers of 0.6 and 0.8 at high angles of attack. These values were calculated at conditions where the tail was at high angles of attack and may be in error as a result of factors that could not be properly accounted for in the method of calculation used. The pitching-moment data indicate that the tail was more effective at high angles of attack than would be predicted. fro?.u es.ttiates based on the lift *curve* of the isolated tail. W differences appear to result from differences in the shape of the Wt curves of the tail when it was on the model as compared to the isolated tail, and are probably associated with local characteristics of th..flow in the vicinity of the tail, such as the spanwise distribution of the downwash and the turbulence level of the flow near the tail. It is believed that the data presented for. these angles of attack still provide a valid indication, at least qualitatively, of variations in tdl contribution to pitching moment and the factors that most affect it.

Tail Incidence for Balance

Fi@re 26 shows the tail incidence required for longitudinal balance as a function of lift coefficient for the model tith the tail in the chord plane extended (center position) and in the metim hi@ position. The center of gravity was in au cases assumed to he at 44 percent of the mean aerodynamic chord. This location was selected as the most rearward point at which a static margin of 5-percent mean aerodynamic chord could be matitained throughout the range of Mach numbers at low to moderate augles of attack and was governed by the stability characteristics of the model with the tail b the center location.

The severe instability of the model without fences =d with the tail 0.U7b/2 above the ~ chord plane is evidenced by the Wge positive incidence angles required for balance at lift coefficients near 0.9. These pos$tive angles of incidence were estimated by -rapolattig the data, stice the tests included only negative and neutr~ settfigs of the tail. The data show that adding the fences had considerable effect in decreasing the magnitude of the testability and in reducing the range of CL for which the instabi~ty occurred. When the tail was in the center position =d with the center of gravity at O.~, the model tith fences was stable at ~ the Mach numbers of the tests and at all lift coefficients, except Just prior to the attainment of -mum lift. It would be expected that other tail locations above the center he but lower than the medium tail would dso *result h* longituditi stabi~ty under au these conditions.

In selecting the vertical Iocatlon of the horizontal-tail surface on an airplane, considerations of ground clearance in the landing attitude, distance from the jet efiaust, and the vertical location and incidence of the wing re~tive to the fuselage often require that the tail be above the wing chord plane. Further tests wotidbe desirable to determine the highest position where a tail might be mounted behind a wing sti~ar to the one that is the subject of thfs report, so as to provide adequate stability throughout the range of speeds and altitudes that would be encountered h flight .

CONCIUSIONS

Wind-tunnel tests of a wing-fuselage-tail combination having a tig swept back 45° and an aspect ratio of 5.5 indicated the folltig conclusions.

1. A large and abrupt forward movement of the center of pressure of the wing-fuselage combination at hi@ angles of attack was a source of static longitudinal instablUty of the c~lete model. When a tall was

added to the model in a position below the wing chord plane, the si@fi-cant variations in stability at high angles of attack were still attri-butable to the wing-fuselage characteristics, but as the tail height was" progressively ticreased to 0.255 semispan above the wing chord plane, the tail produced increasingly powerful positive pitching moments.

2. For the model both with and without the. tail, leting-edge fences at ~4-percent and 69-percent semispan reduced the forw~ Senter-of-pressure movement accompanying stall% of the wing (prior to maximum lift) and, at Mach numbers up to 0.85, substantially increased the l"ift coefficient at which instability occurred.

3. A leading-edge chord extension between the wing tip and the 44-percent semispan station resulted in an improvement b stabi~ty that was similar to that protided by the leadin"g-ed~" fen~afl.

4. At Mach nmbers up to 0.9, rapid increase of effective downwash at the tail with increasing angle of attack rem_lted.=~ ~eased contri-bution of the tail to stability, but when the tail was lmred to the wing chord plane this decrease waa delayed to higher an@es of attack.

5. The effects of adding fences were to reduce or e~inate the decrease in the contribution of the tail to stability.

6. Significmtvariations of static longitudinal sta}ility with lift coefficient are indicated ti data for ~ the model configurations investi-gated, but the model tith fences and @th the tail near the wing chord plane would be stable at au of the Mach nwbers"of the test and at all. lift coefficient (except those at or just prior to maxim~ lift) if the center of gravity were kcated so as to provide. a tinimum static margin~at "" low angles of attack of 5 percent of the,me~ a~odynamic chord.

Ames Aeronautical Laboratory
National Advisory Committee for AeronautLc6
Moffett Field, Calif., Nov. 9, l%k

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1. Johnson, Ben H., Jr., and Shibata, Harry H.: Characteristics Through-out the Subsaic Speed Range of a Plane Wing and of a Cmbered and Twisted Wing, Both Hating 45° of Sweepback. NACARM A5~27, 1951.

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10. Cahill, Jones F., and GottUeb, Stdey M.: --Speed Aerodynamic Characteristics of a Series of Swept Wings Having NACA65A006 ~r-foil SectIons. NACARM L9J20, 1~0.

TAB~ I.- COORDINA~ OF CEORD-~ION SECTION NO- TO QUARTER-CHORD L~

[All dtiensions in percent of chord of original section]

Station	Otiinate
-15.0	0
-14.3	.80
-13.9	1.00
-13.0	1.30
-11.9	1.60
-10.0	2.00
-7.0	2.50
-3.0	3.00
	:.:;
::;	
17.0	4:50
'25.3	4.80
35.1	4.97
4Q. 0	5.00

TAHLE II. - G~ OF ~ MODEL

Wing (without kading-edge e-nsion)	
Aspect ratio	5.50
Taper ratio	0.532
Sweep of quarter-chord line, deg	45
Section normal to quarter-chord line	NACA 64A010
Area (semispan), sqft	3.812
Meanaerodyn=ic chord, ft	1.215
Dihedral	0
hcidence	0
Positiononbody	on =is
Wing leading-edge chord extension	
Streamwise distance to extended leading edge	0. 17c
hcations of inboard ends of extensions	0.44b/2, 0.57b/2, o.6gb/2, o.82b/2
Wing fences	
Distance aheadofwingkading edge	O.*C
Spanwiselocations	0.4hb/2, 0.57b/2, o.69b/2, o.82b/2
Chordwise extent (from leading edge)	0.25c, 0.50c, 1.00c
Fuselage	
Fineness ratio	12.5
kn@h,ft	7.292
Frontdarea/tingarea	0.035
Horizontal tail	
Aspect ratio	4.0
Taper ratio	0.5
Sweep, deg (50.p~rcent chord)	
Section	N~A 63A00!
Area (setispansqft}	0.945
Tail length(Zt)	-= 2.0E
Vertical distance above wing chord ptie extended	
kwtail	-0. E7b/2
Center tail	
Medium tail	0. =7b/:
Hightail	0. 255b/2

Tm~ ~.- CORREC!TI~S TO DATA

(a) Constriction due to tunnel walls

Corrected Mach number	Uncorrected Mach number	qcorrected / quncorrected
0.25	0.250	1.001
~:	.399	1.002
	* 797	1.004
:?	.846	l.om
	.893	1.008
.92	.911	1.010

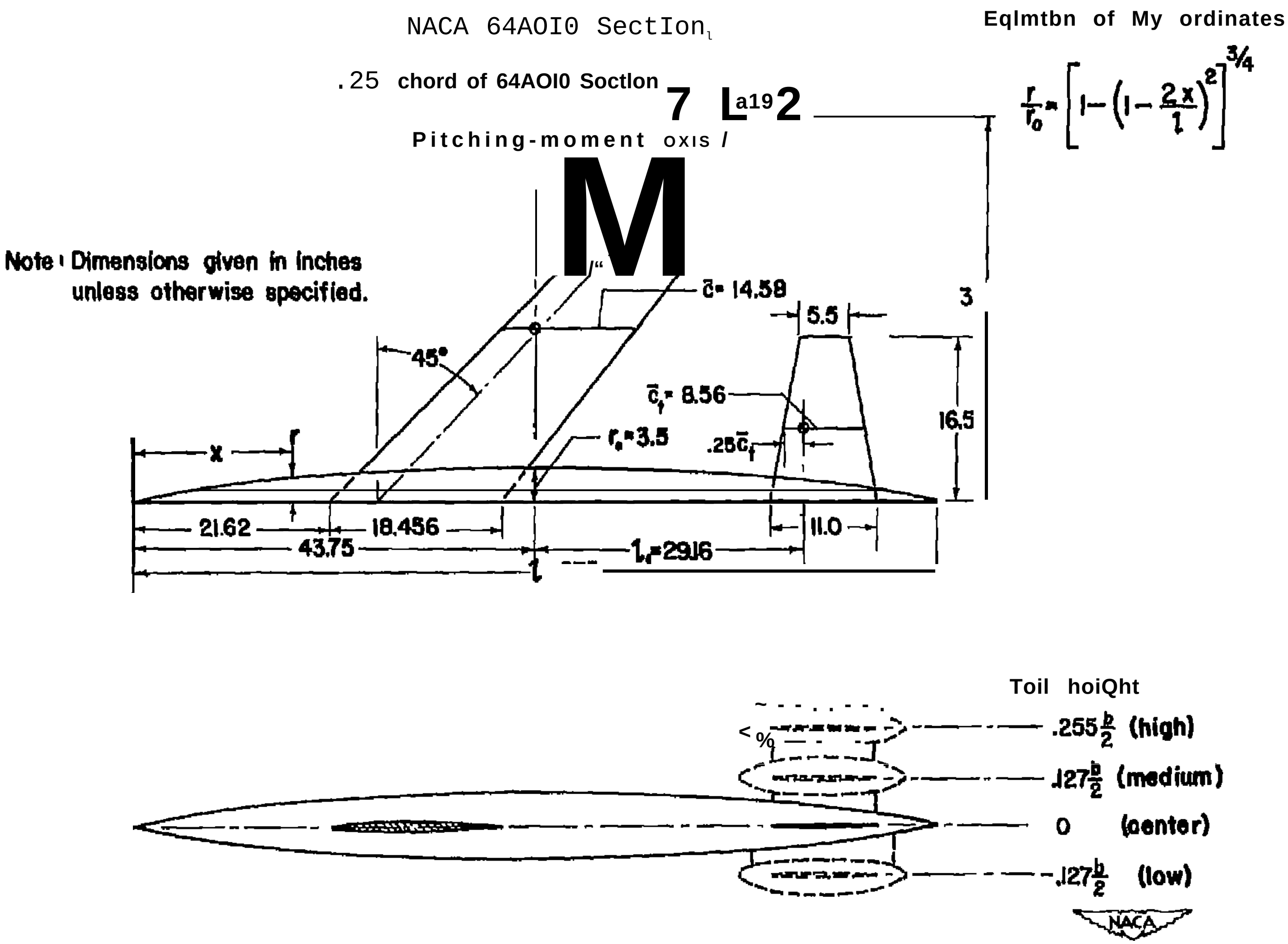
(b) Jet-bound- effects

~	K= - Aa / CL	A % K 2 = q (wing body)	& =A + (wing body tail)
0:5	0.349	-0. Oou	0.0038
	.349	-.oQlo	.0052
	.349	-.0008	.0080
:;5	.349	-.oti	. oo~
	; :::	-.0001	.0114
":;2		.0001	.0123

(c) Tare corrections

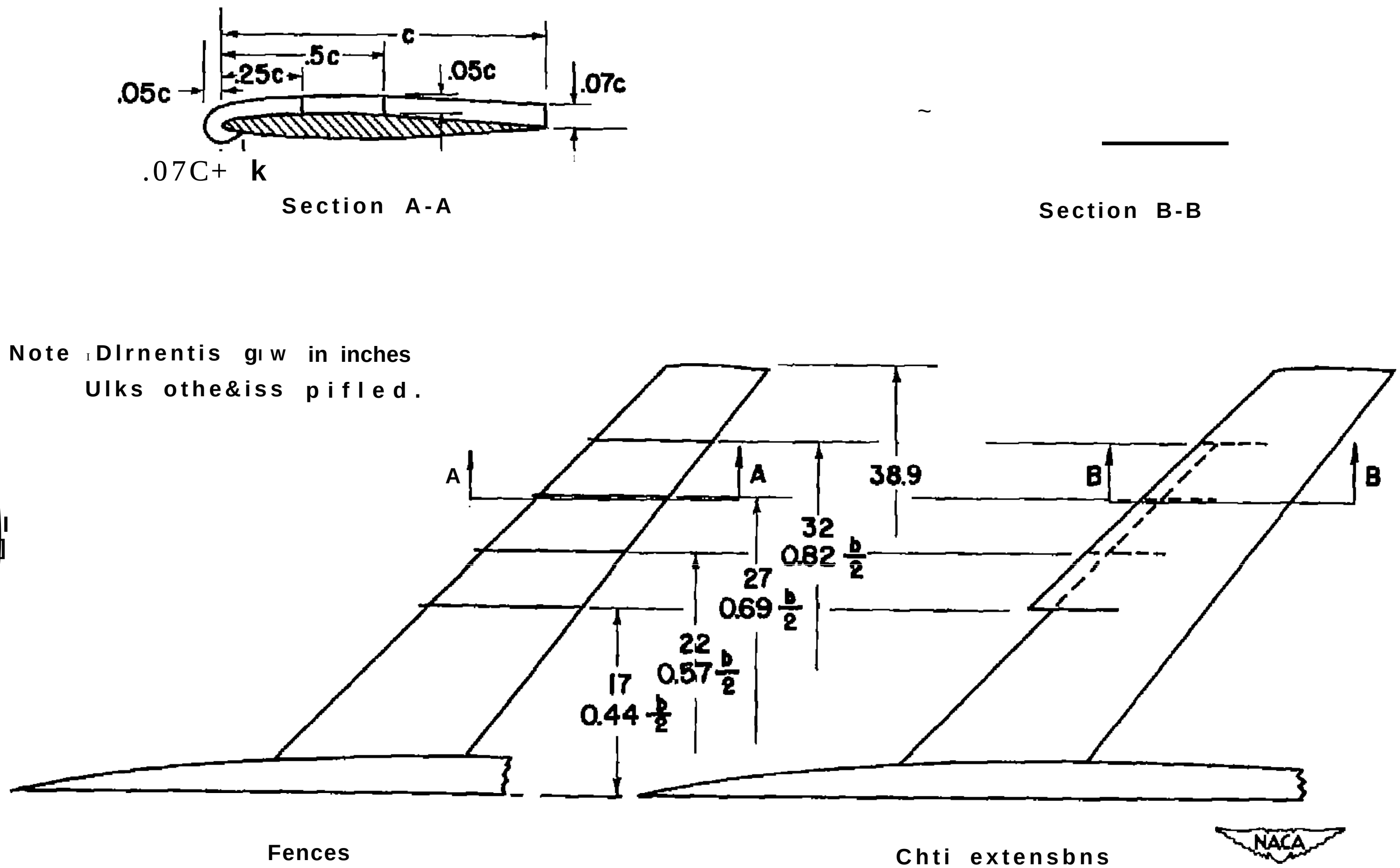
Repolda number	Mach nutnber	c=tare
10,000,000	0.-	0.0049
2,000,000	.25	.o@o
2,000,000	.60	. C)ql
2,m,ooo	.80	.0057
2,000,000	.85	. OMO
2,000,000	.90	.0064
2,000,000	.92	.0067

~



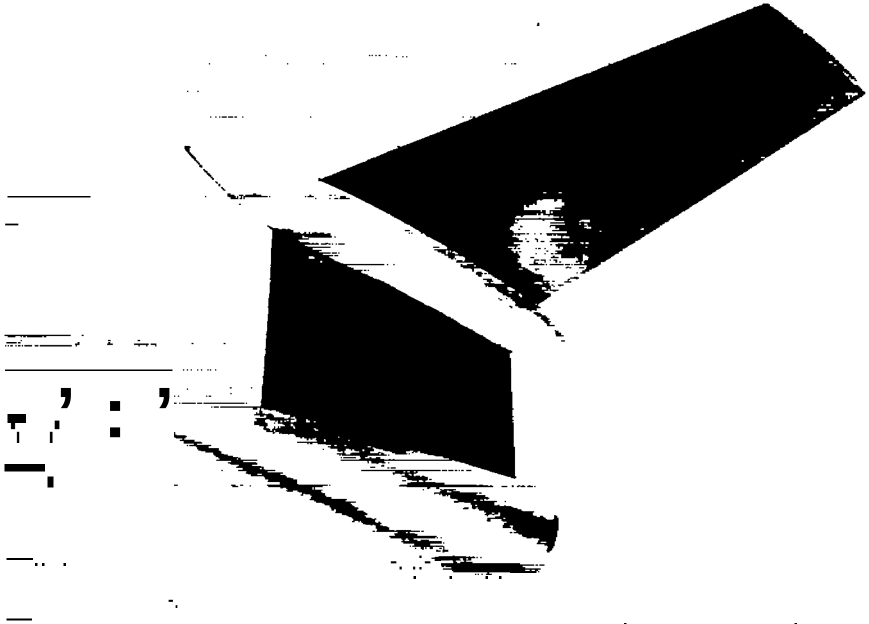
(a) Compiete model and W1 hel@t6.

Figure 1,- Dra~~ of the model.



(b) Fences and leading-edge extensions.

Figure 1.- Concluded.



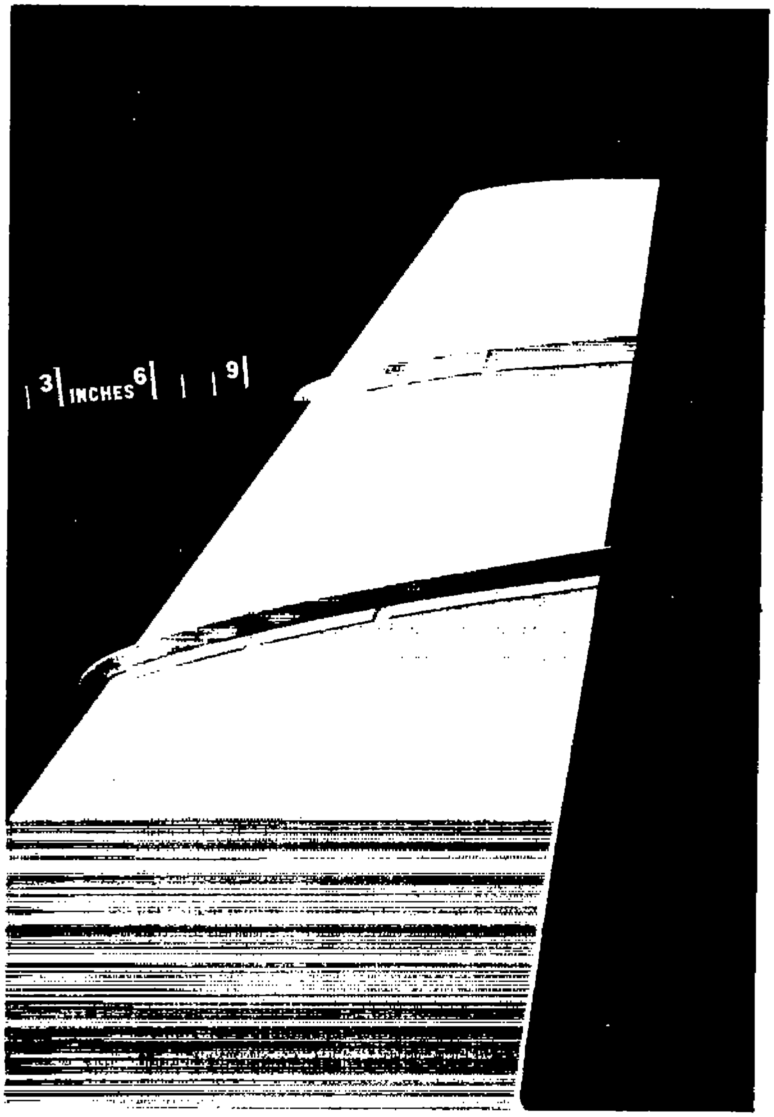
A-19237.1

(a) High tail position.

A-19238.1

(b) Low tail position.

Figure 2.- Photographs of the model.



A-lqi'82

(c) Full-chord fences at 0. &&b/2 and o.6gb/2.

Figure 2.- Continued.

A-18987

(d) Model with a Ieading-e@ chord efinsion between 0.44b/2 md the tip.

Figure 2.- COnC~~d~.

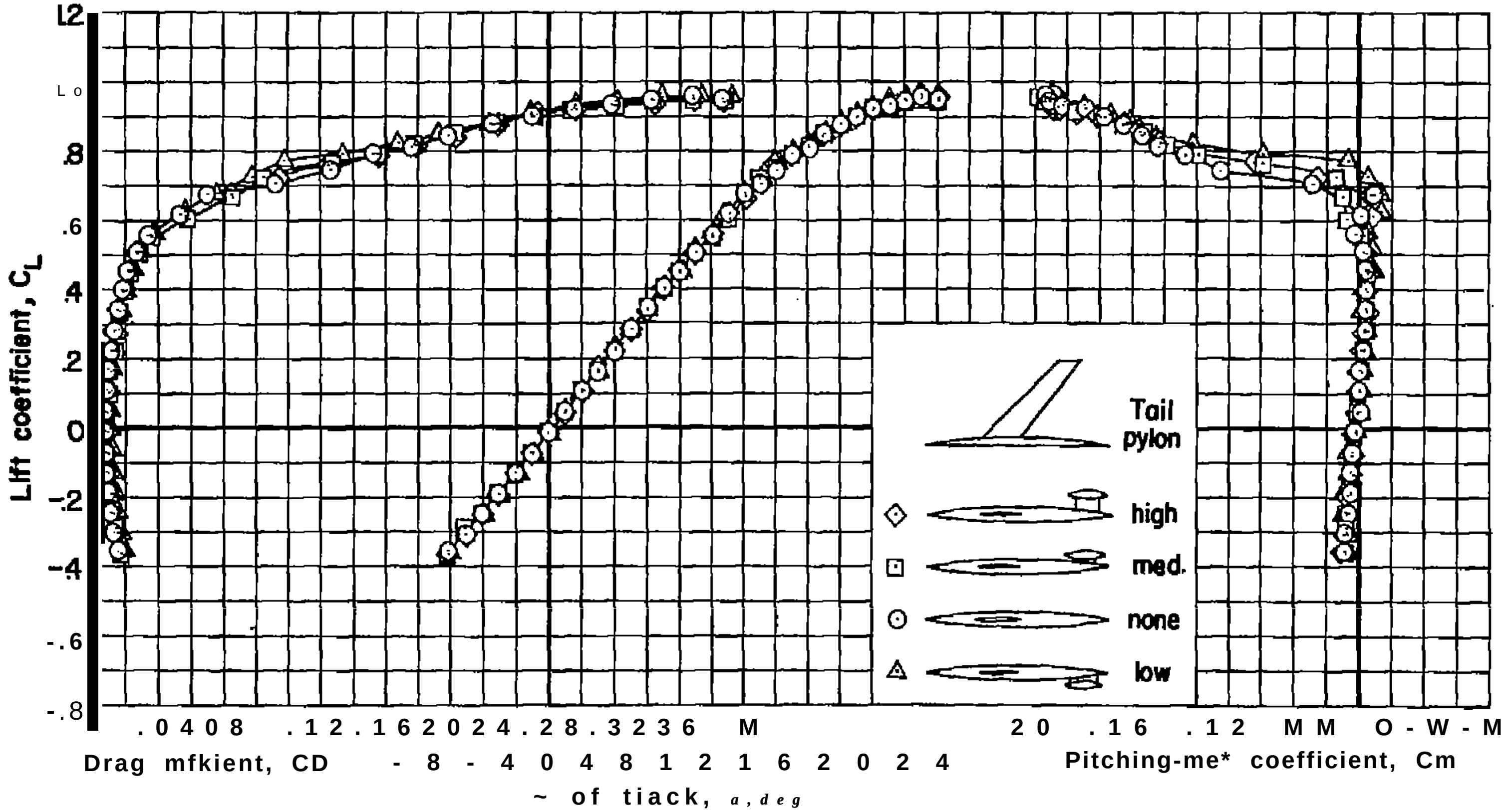
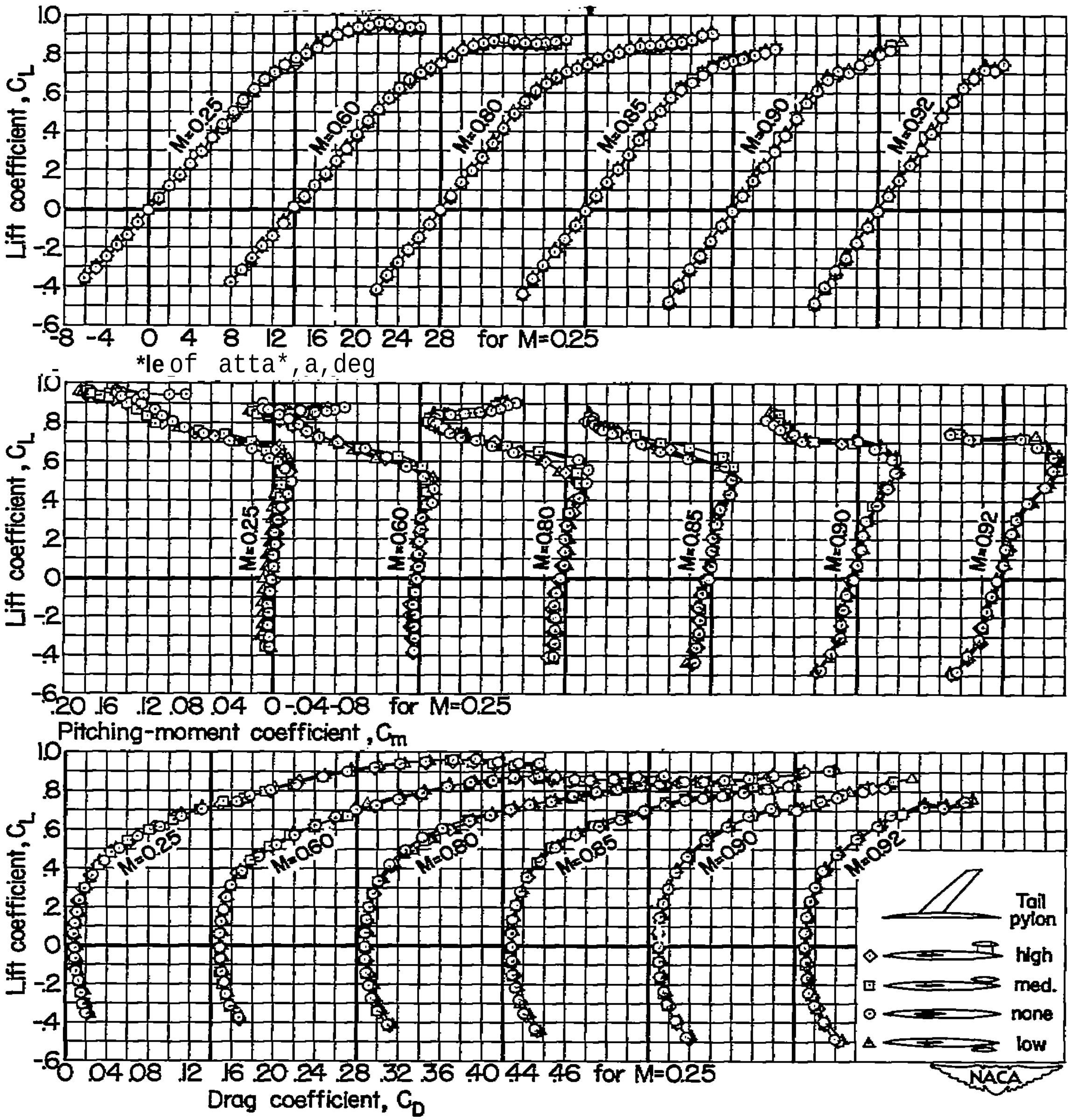


Figure 3.- ~e aeroxic charac~rlstics of the mcdel wit?a the tall off and with various tail Buppoti pylons at a Reyno~s number of 10, ~0, ~; M = O. 2'j.

A54K09



Fi~re 4.- me aerodyn=ic characteristics of the model with the tail off @ tith various tail mpport pylons at several Mach ntiers; R = 2,000,000.

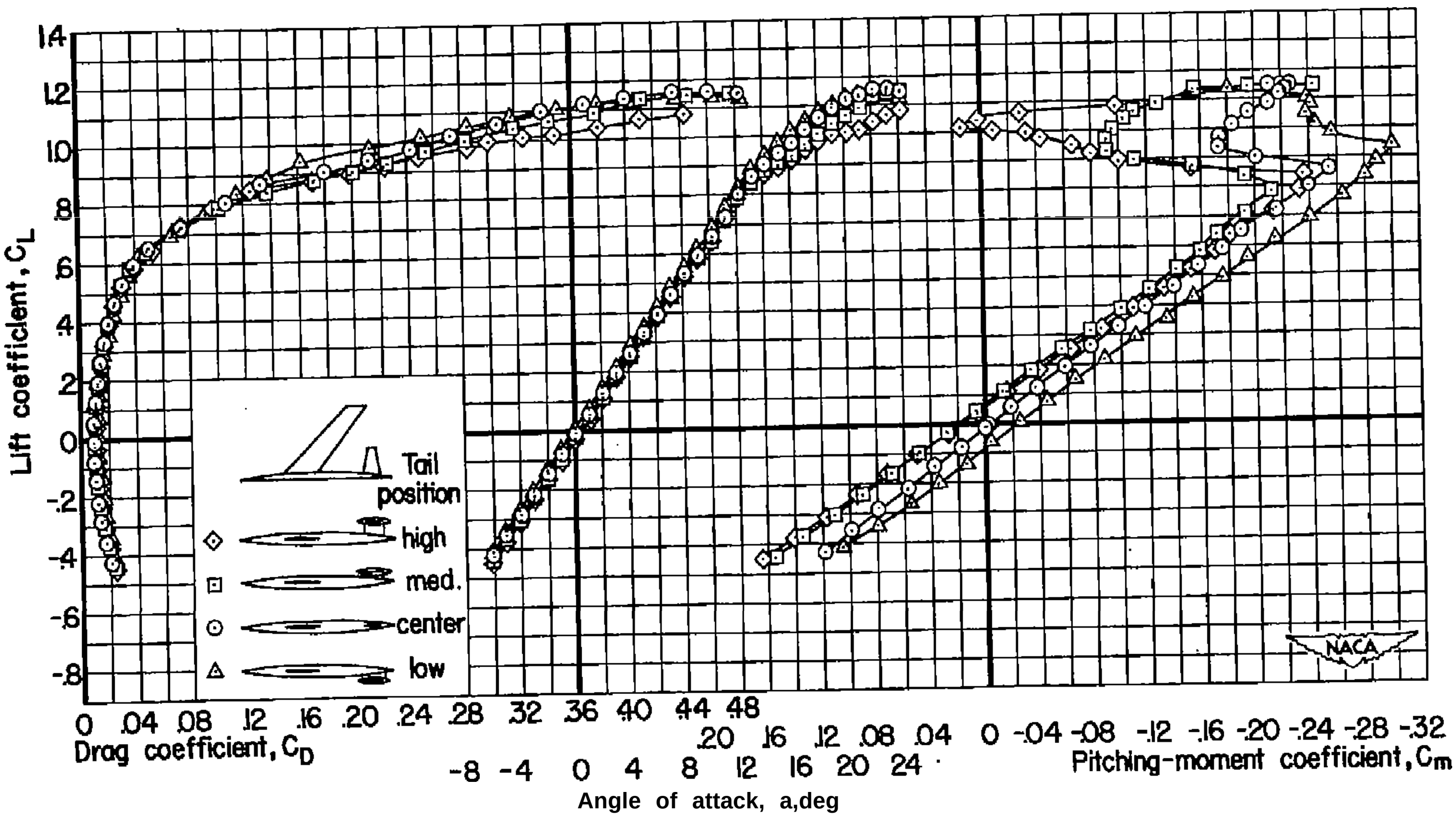
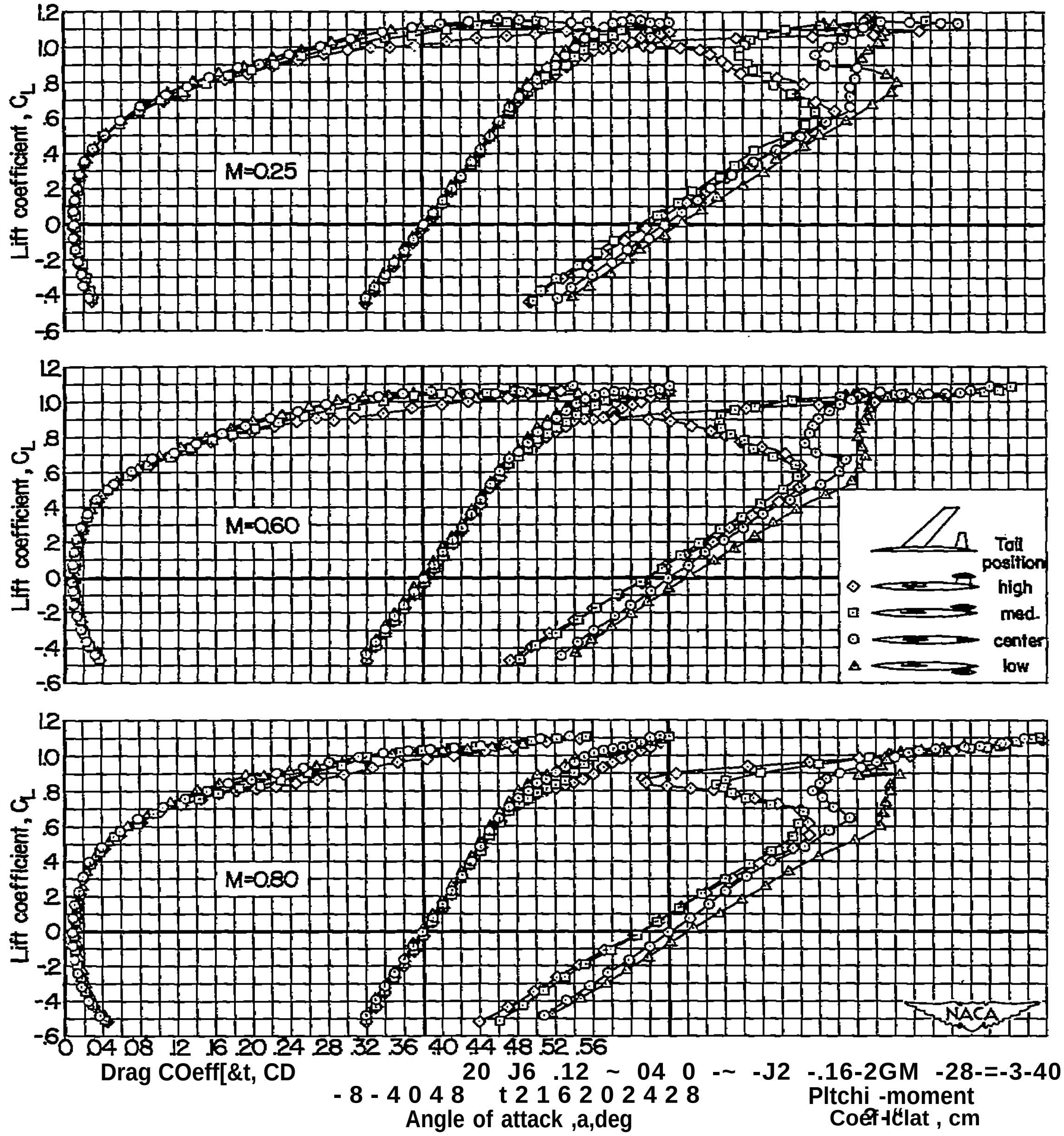


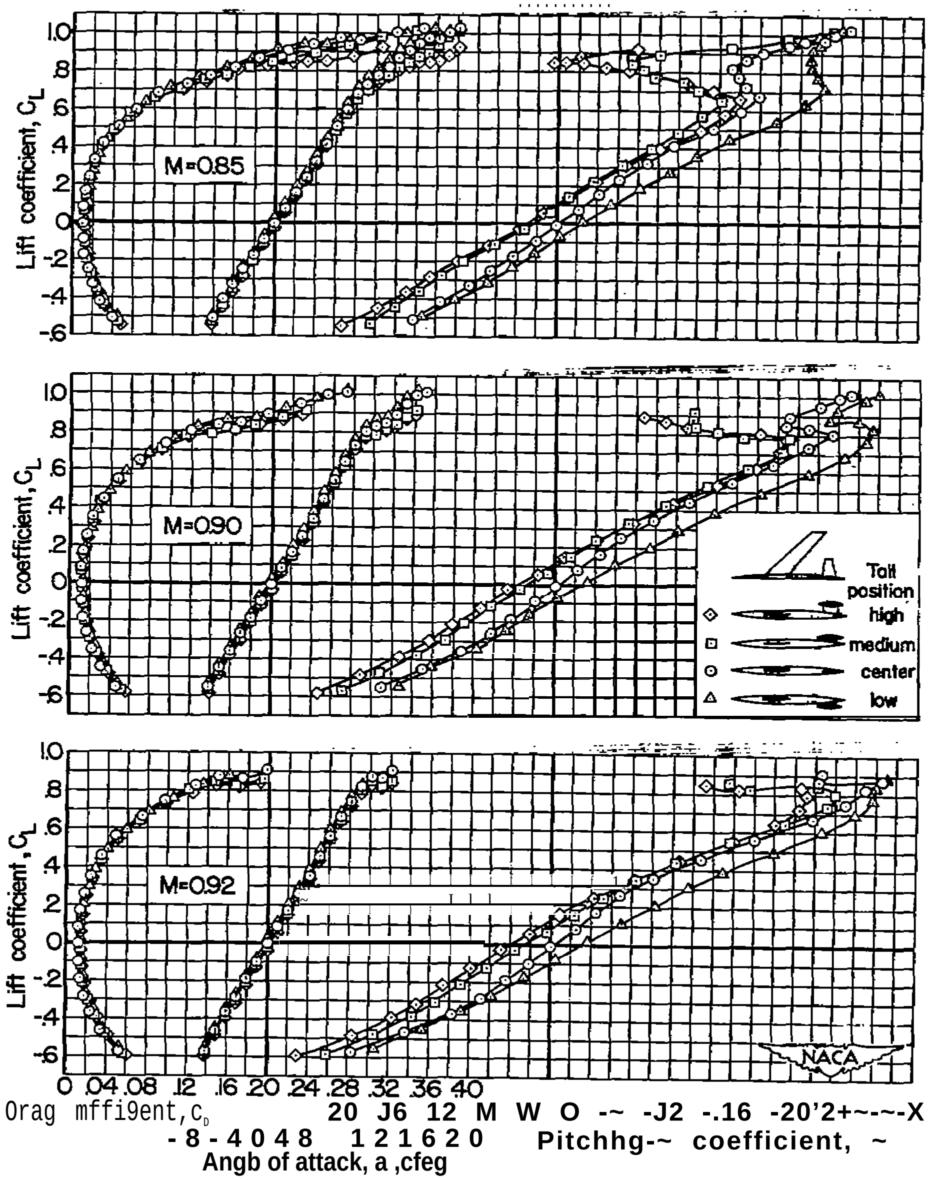
Figure 5.- The effect of tail height on the aerodynamic charactiritiics of the del at a ReYIIOMS number of lo,o~,ooo; ~ =0“~-

NAC *# & g



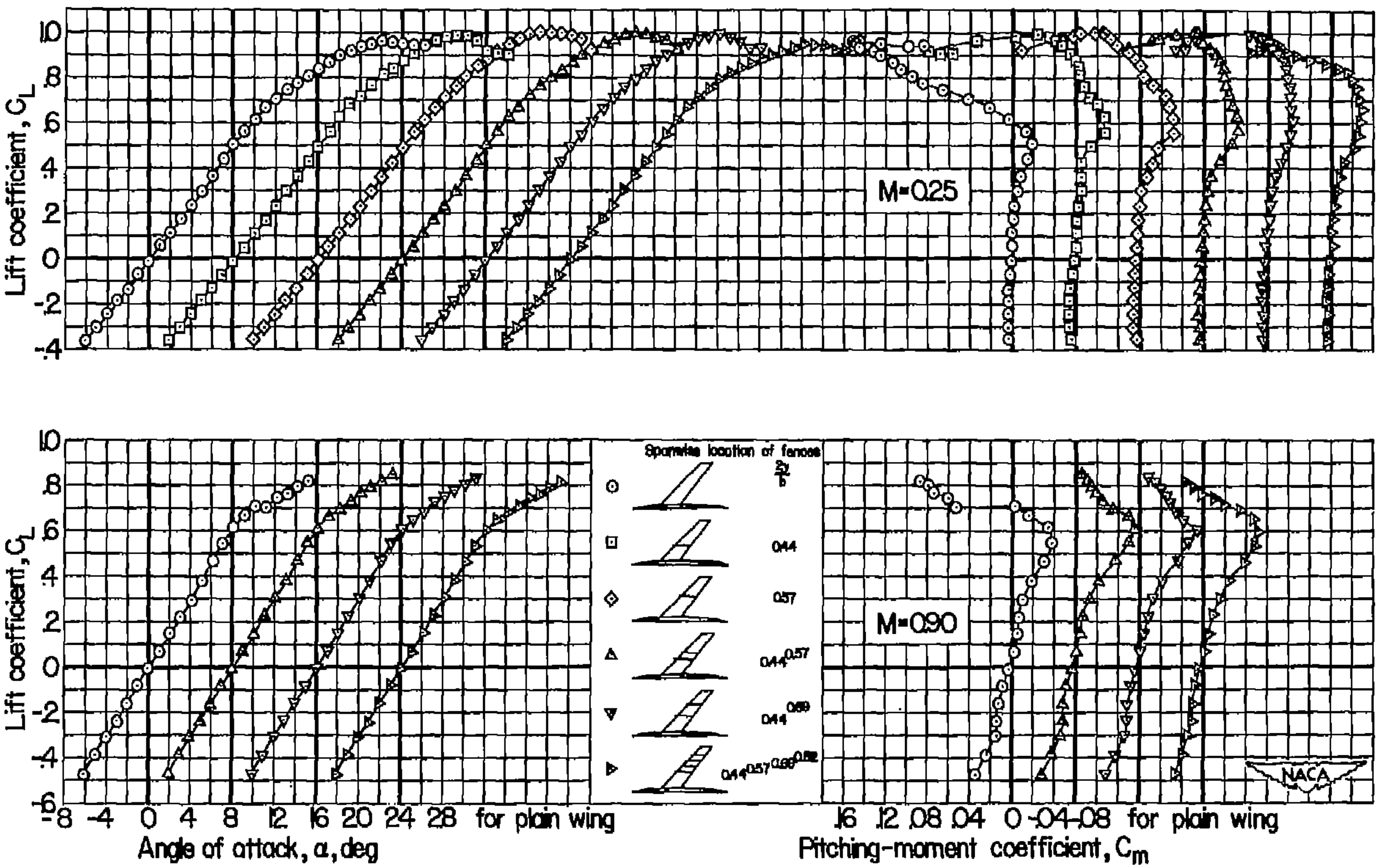
(a) M = 0.=, 0.60, and 0.80.

Figure 6.- The ef feet of tail height on the aerod-ic characteristics of the model at various Mach nmbers; R = 2,000,000.



(b) M = 0.85, 0.90, and 0.92.

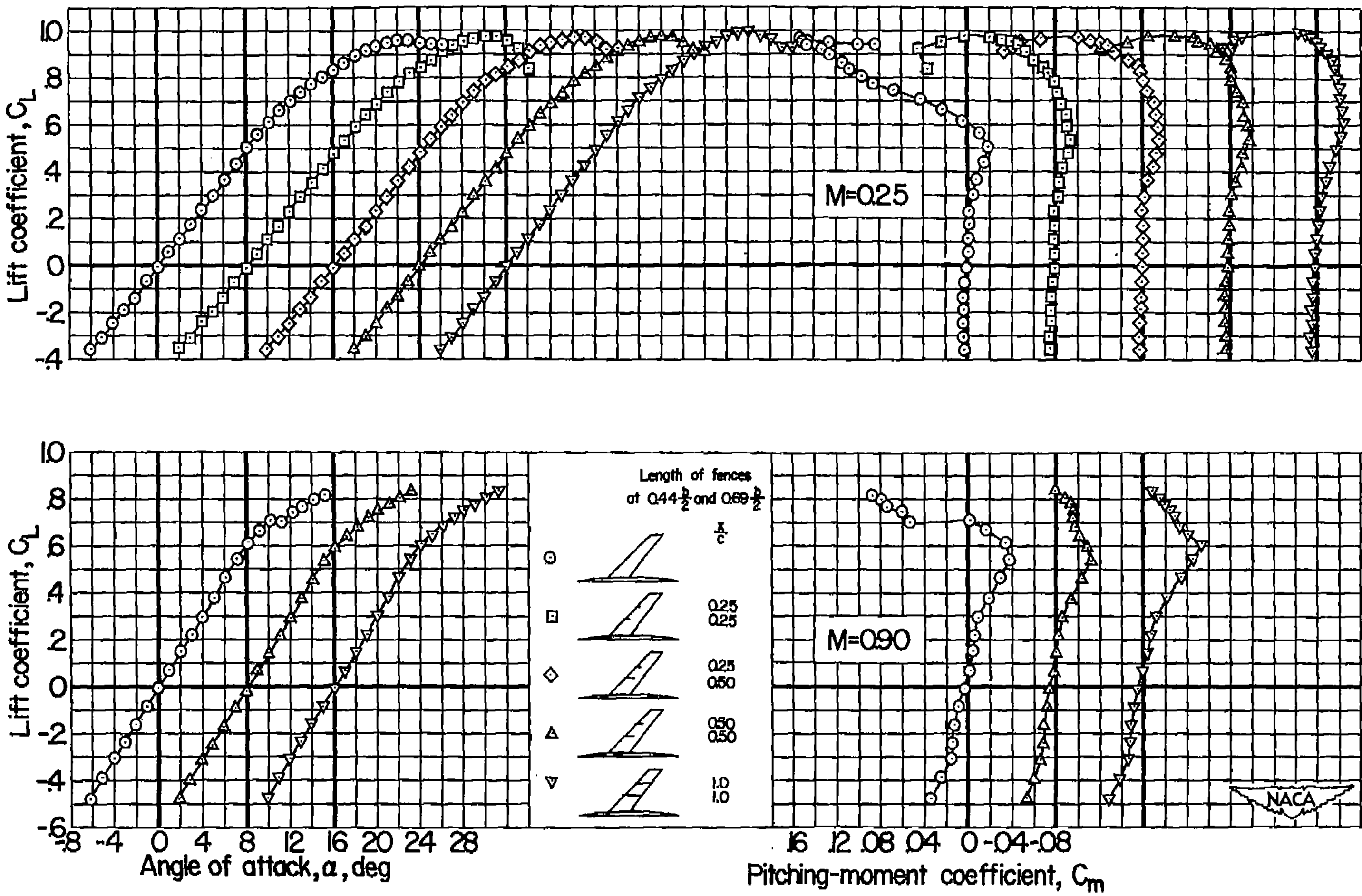
Figure 6.- Concluded.



(a) Effect of Span location.

F1.gure 7.- Uft and pitching-moment characteriEtlcs of the model tith tie tall off and with v~ouB combinations of fences at Mad numbers of O.~ and O.W; R = 2,000,~.

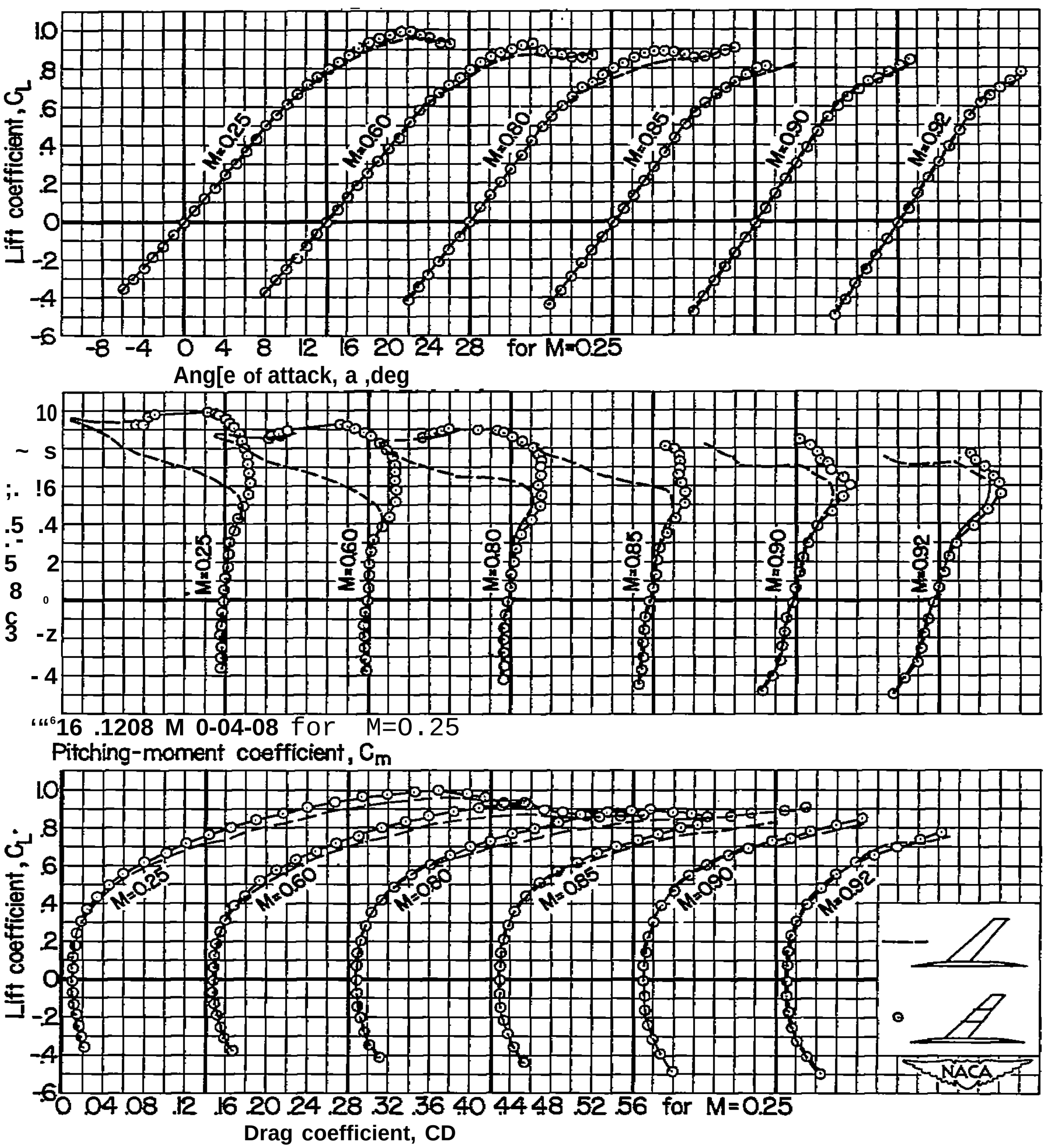
[redacted]



(b) Effect of fence length.

Figure **7.-** Concluded.

[redacted]



Fiwre 8.- ef feet of fences at 0.44 and 0.69 setispan on the aero - d~mic characteristics of the raodel with the tail off at various Mach nwbers; R = 2,000,000.

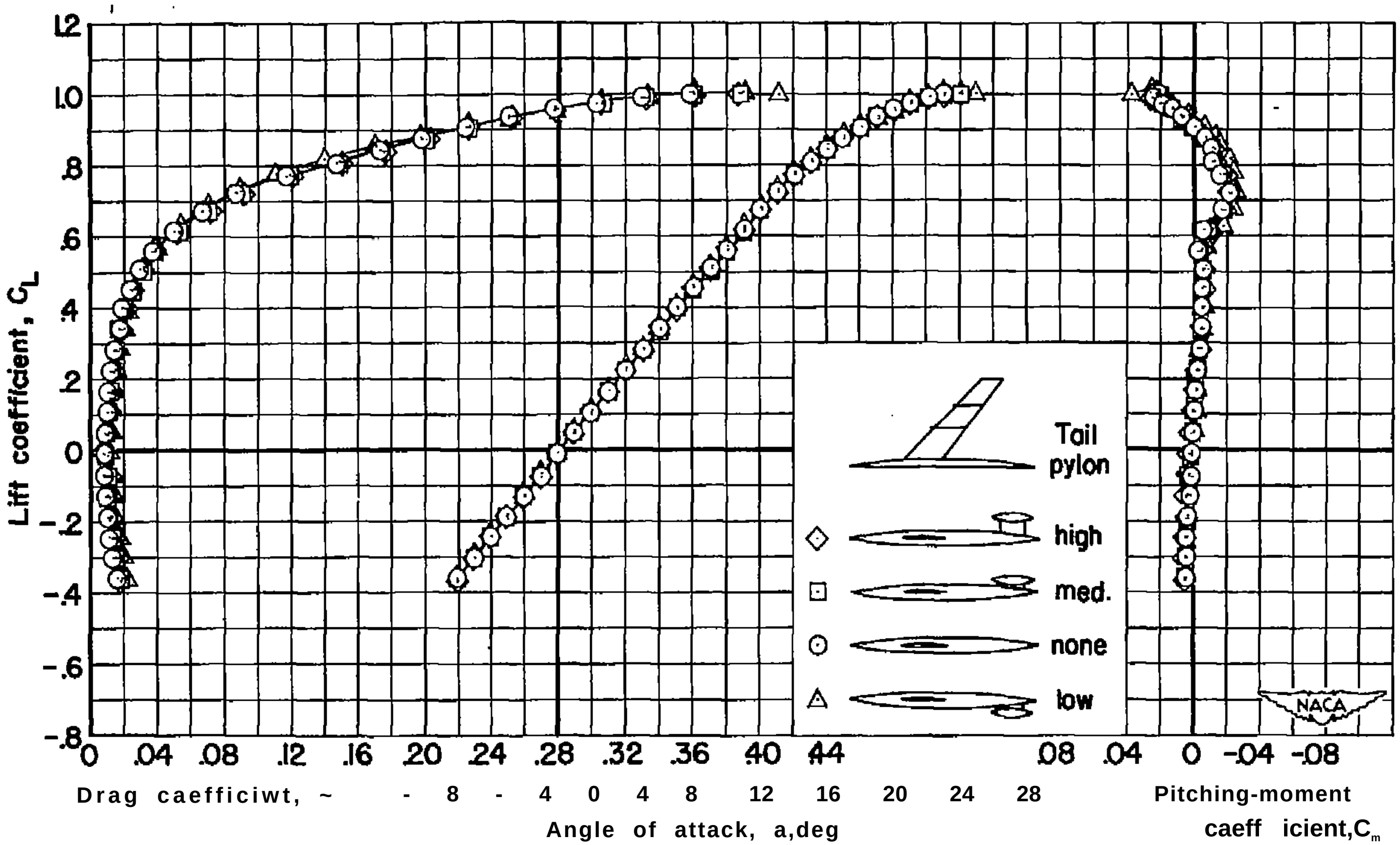


Figure 9.- The aerodynamic characteristics of the model with I'ences at 0. U md 0.69 semispan, Gil off, and witivarioua tail Wport pylons at a Re~lds number of 10, O~,000; M = O.=.

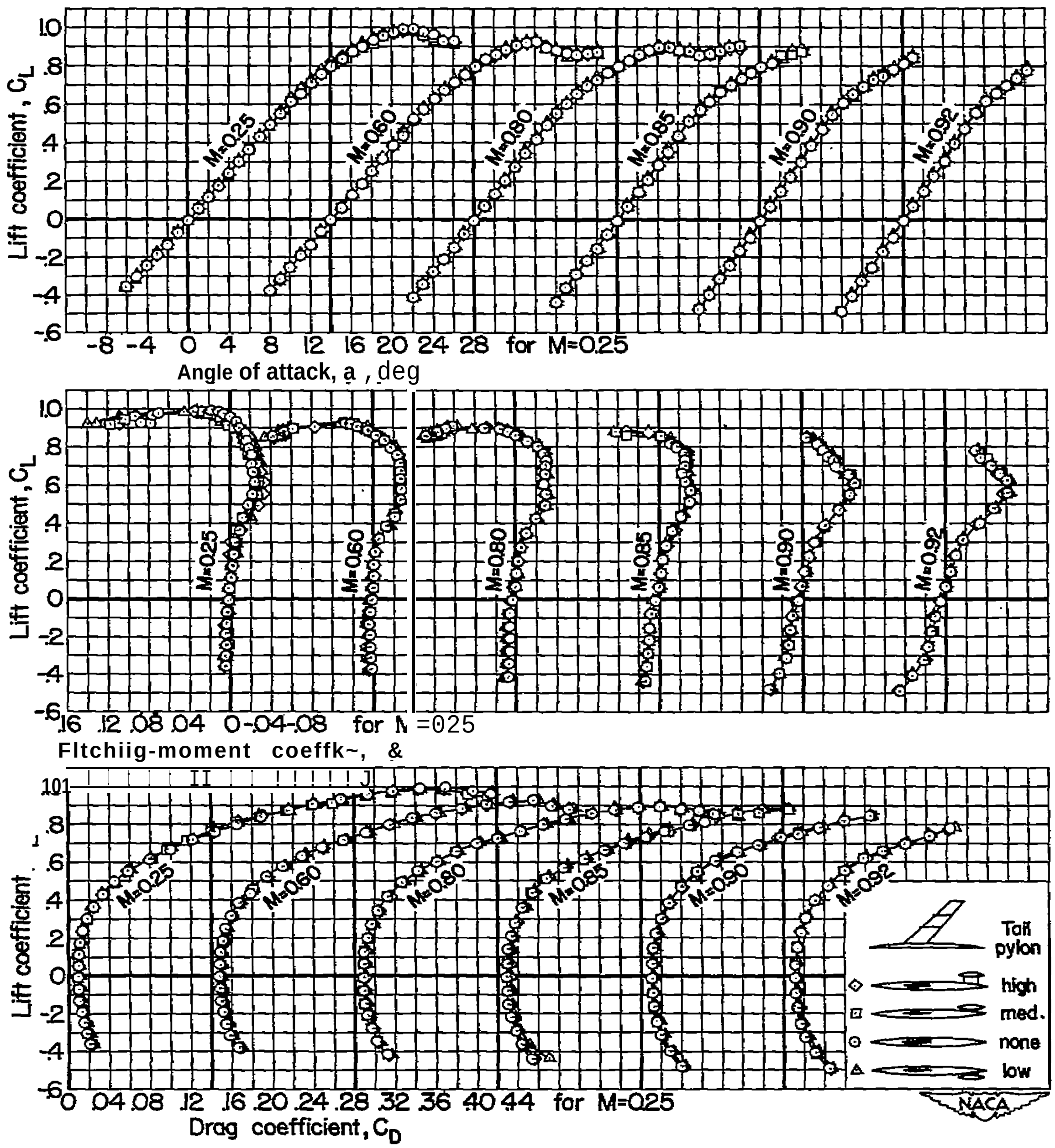


Figure ‘10. - The aerodynamic characteristics of the model with fences at 0.44 and 0.69 saispan, tail off, and with various tail support pylons at several ~ch nmbers; R = 2,000,000.

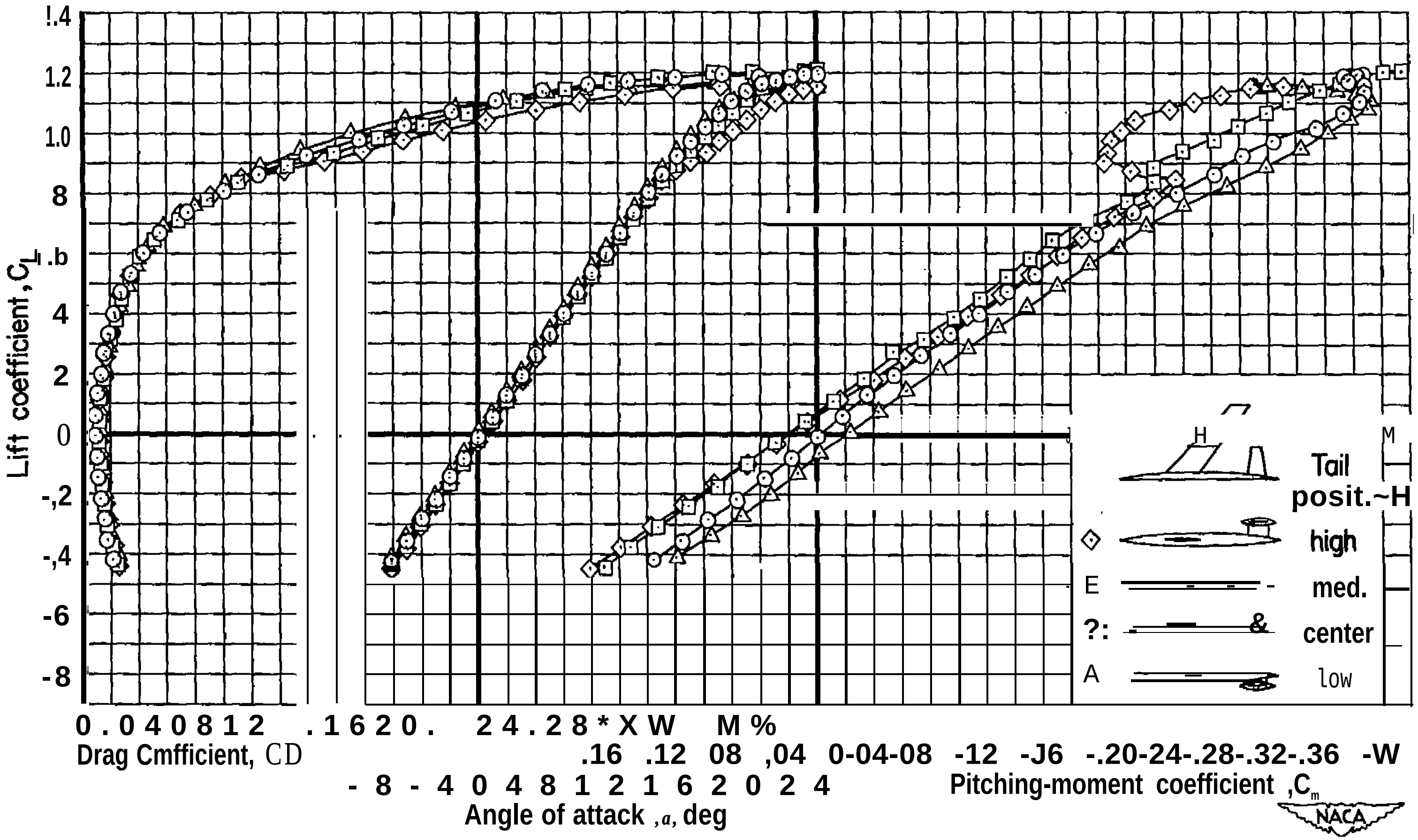
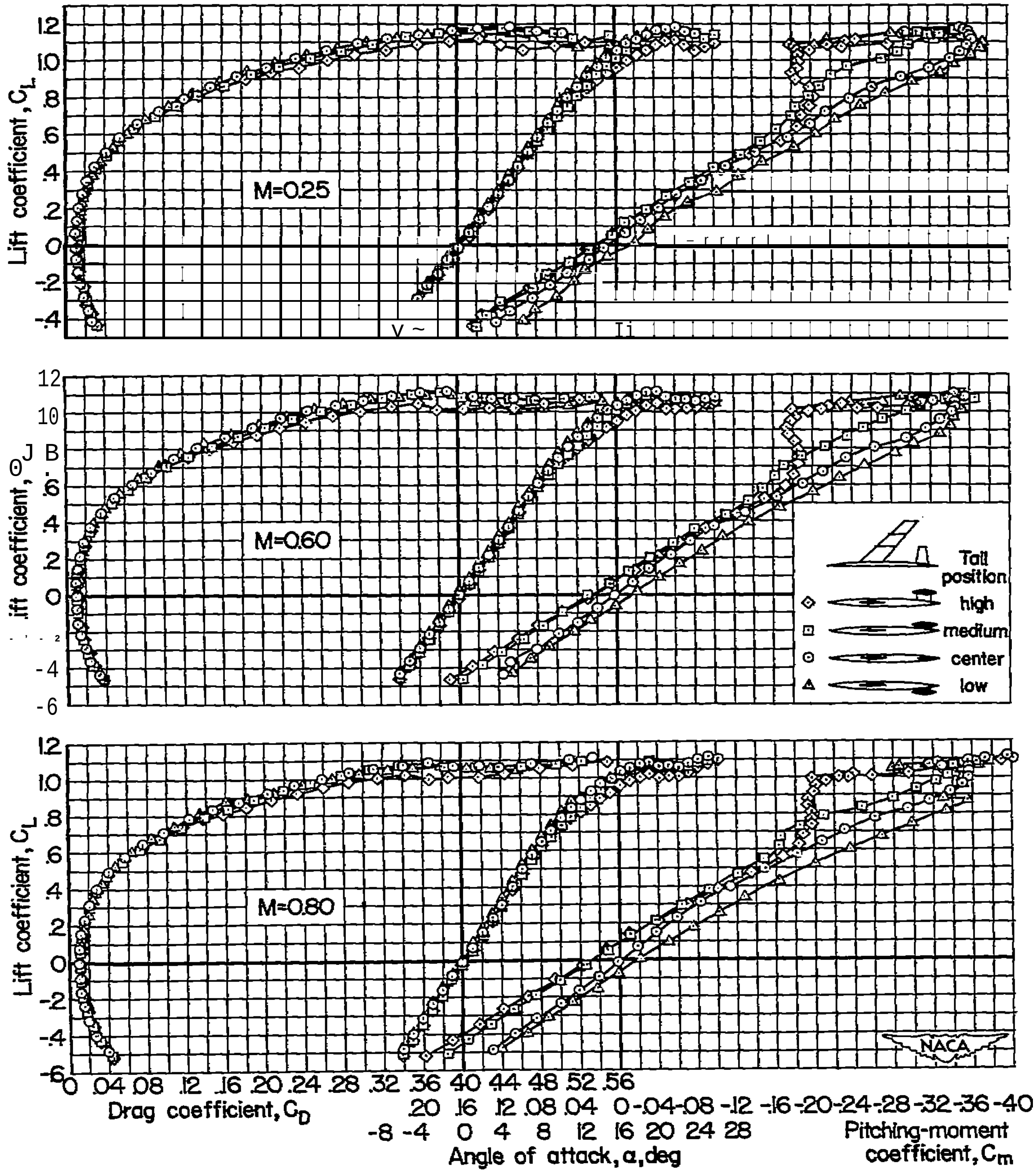
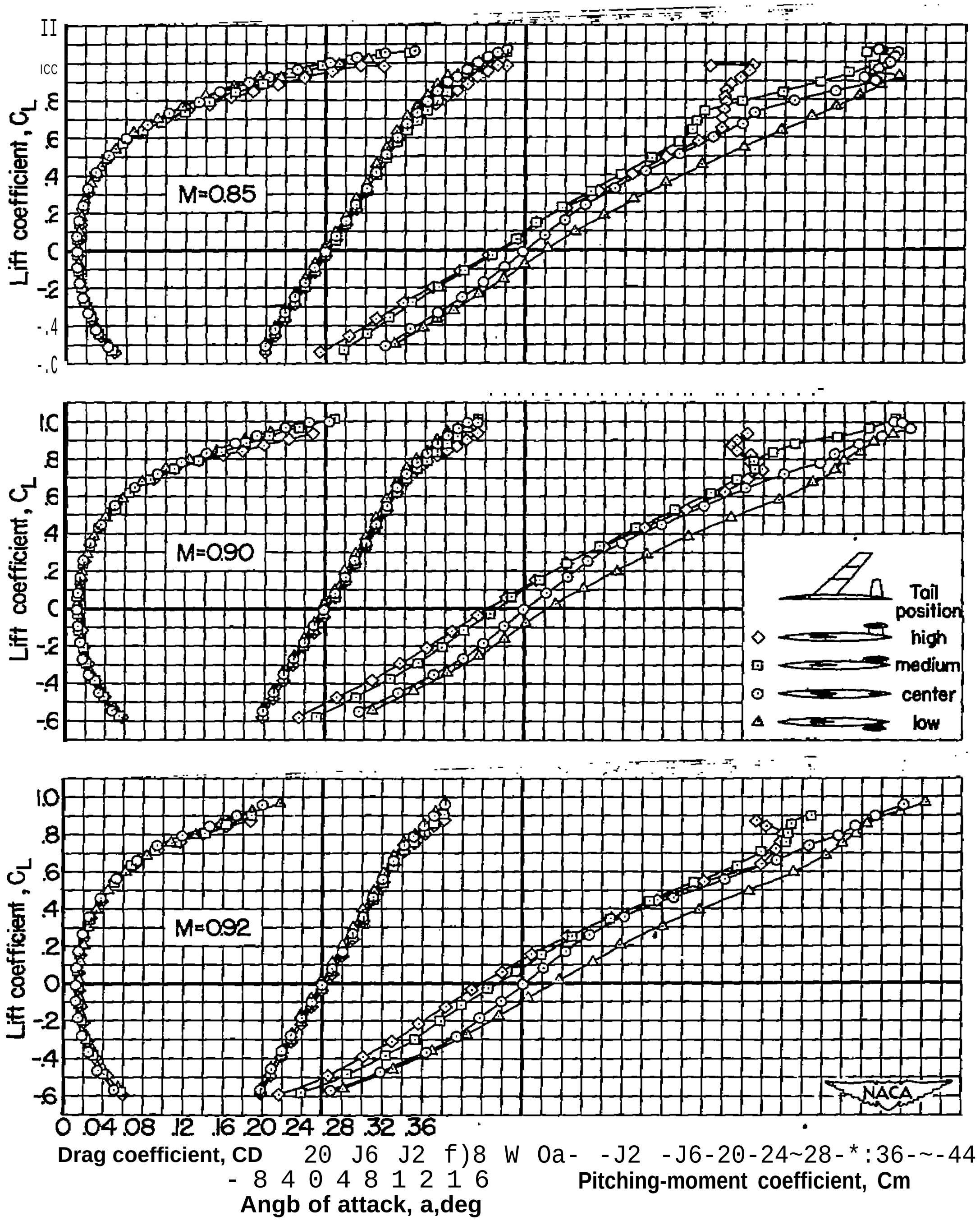


Figure 11. - The effect of tail height on the aerod~amic characteristics of the model with fences at O.~ and 0.69 semi~a at a Reynolds number of 10,000,000; M = O,=.



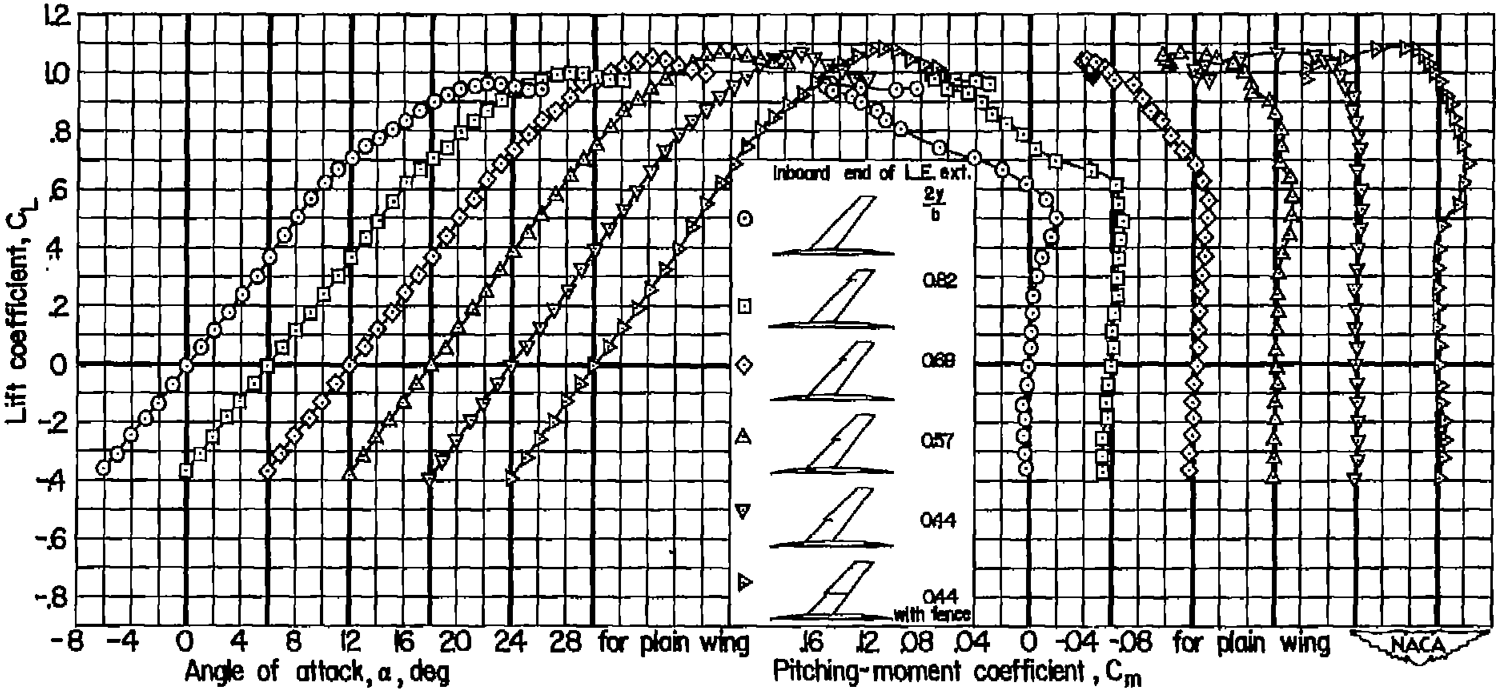
(a) ~ = 0.25, 0.~, and 0.80.

Figure 12. - The effect of tail. height on the aerodynamic characteristics of the model with fences at 0.44 and 0.69 semiqan at various Mch numbers; R = 2,000y~-



(b) M = 0.85, 0.90, and 0.92.

Figure 12. - Concluded.



Mgure 13. - Mft andpitch~--nt characteristics of the mdel tith the tail off and with various le~~-edge extension~ and e I.eading-eQe extinaion-fence combination at a Mach n~ber of 0.3; R . 2,000,(XKI.

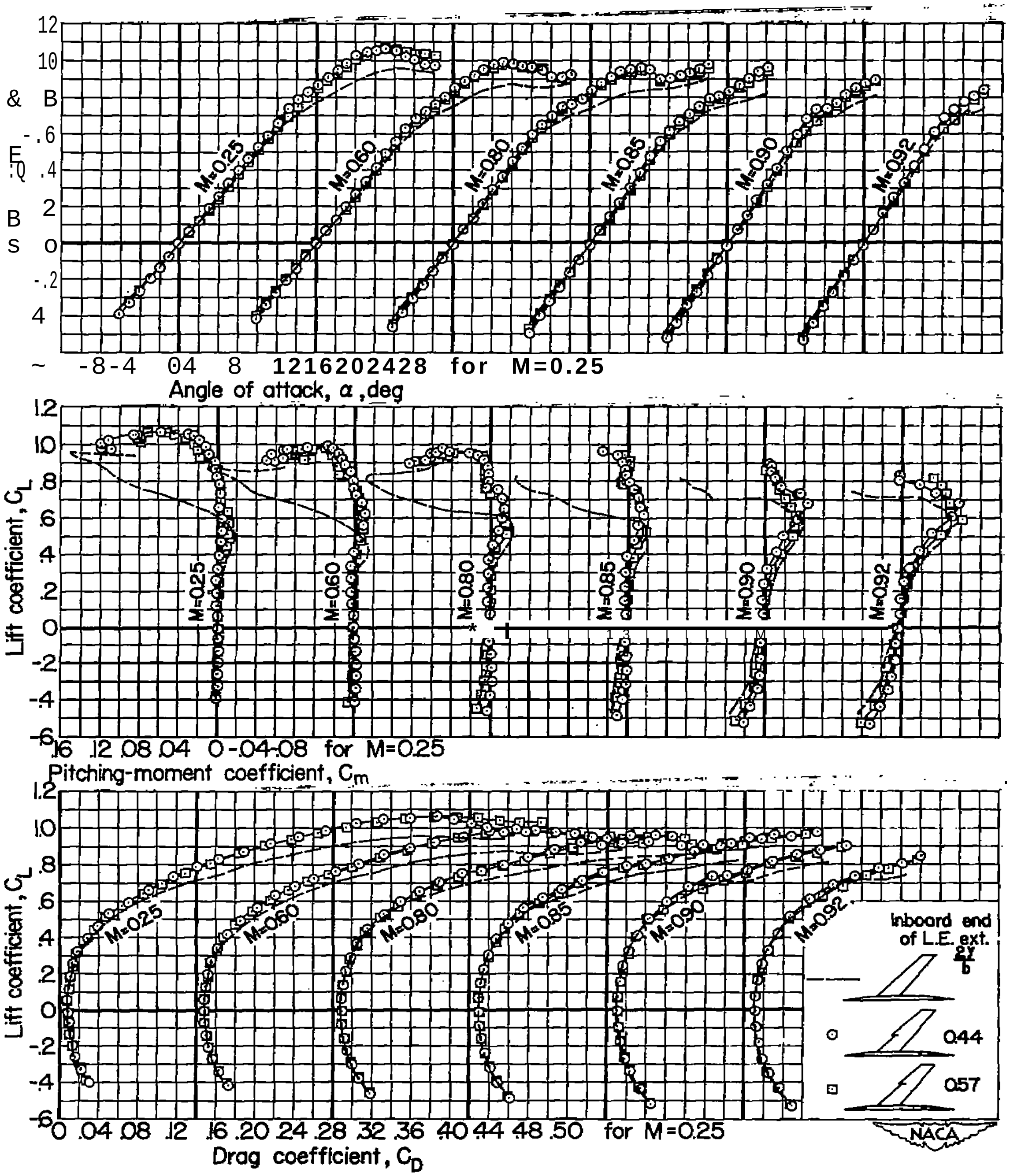
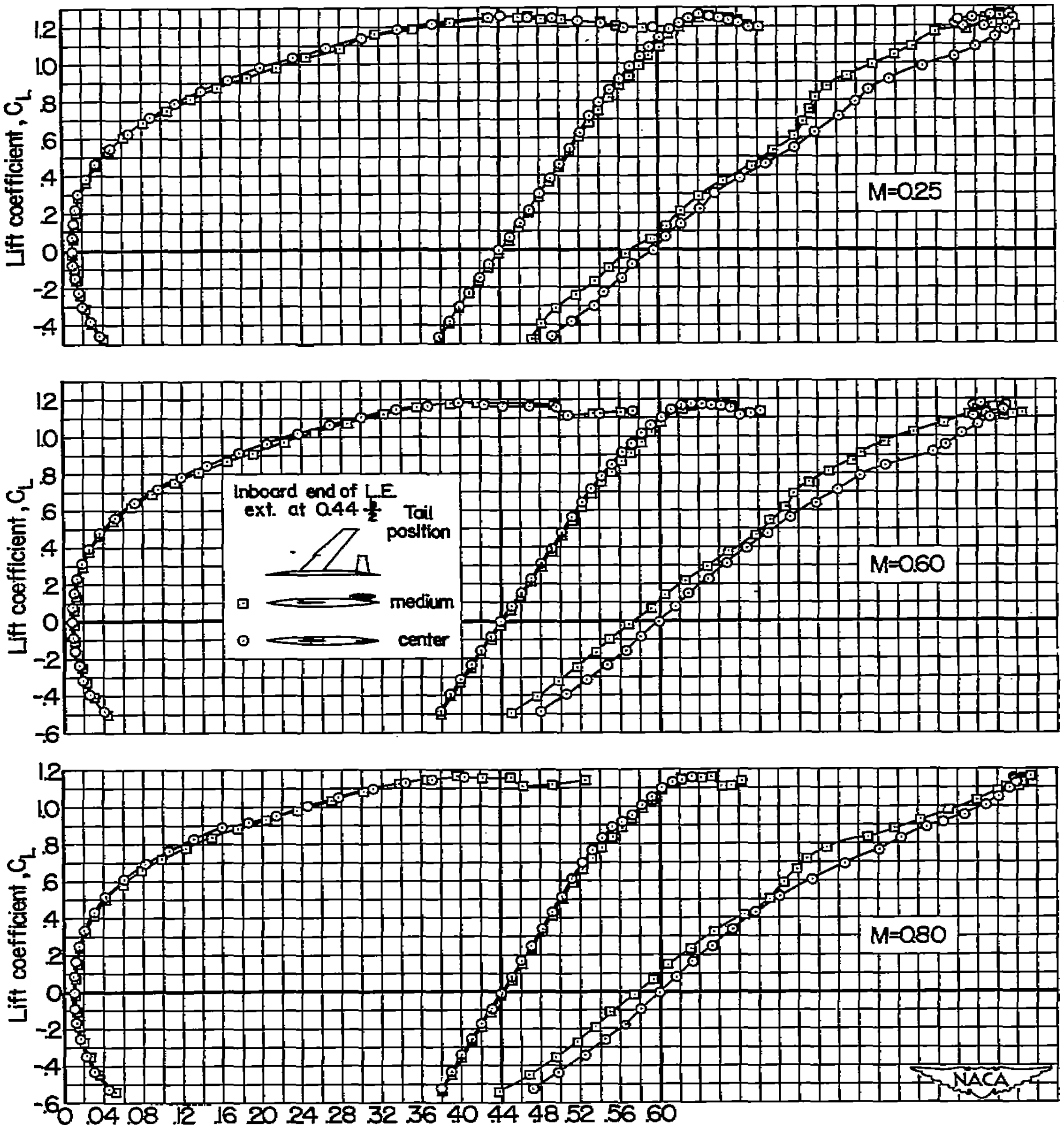
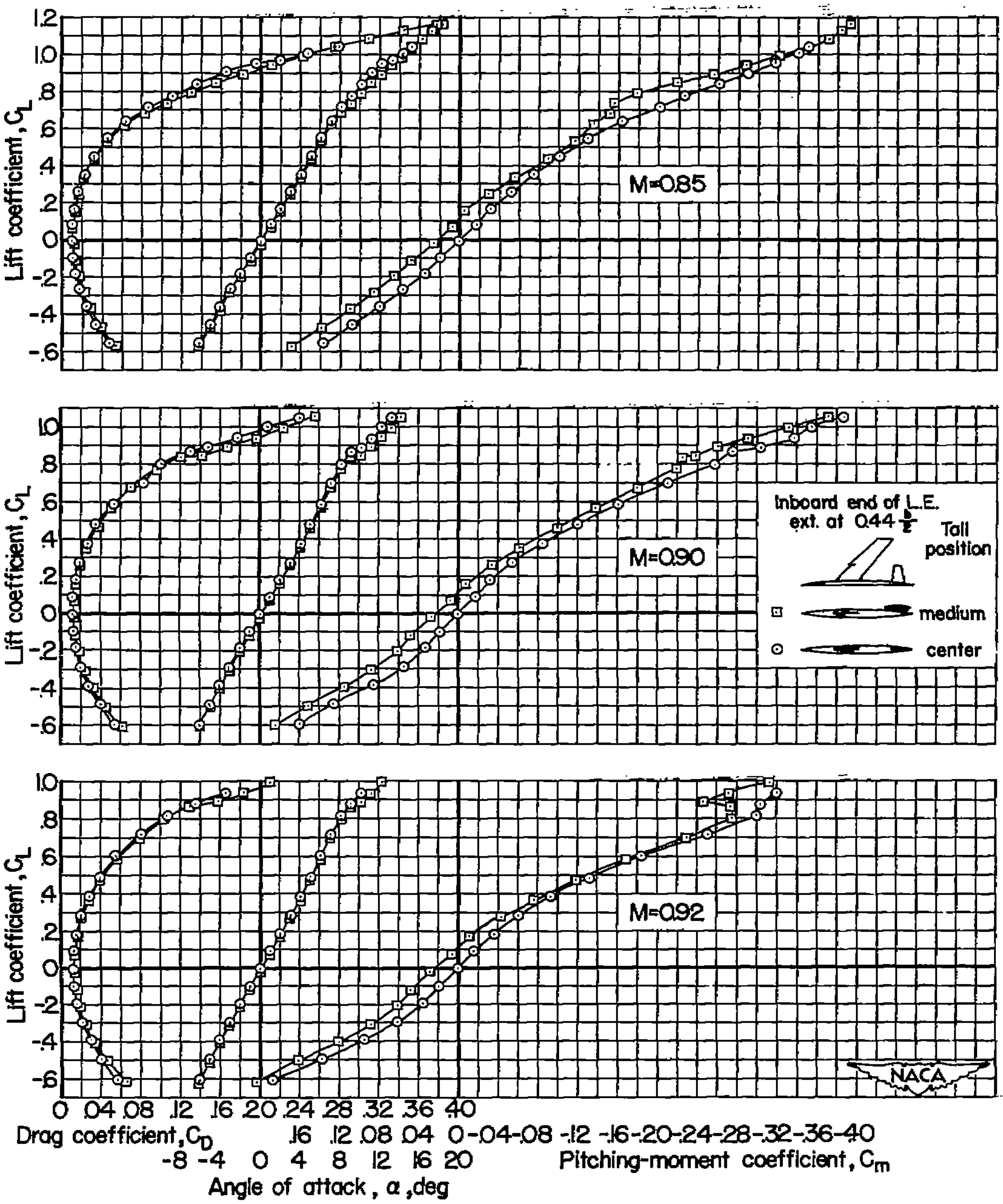


Figure 14. - The effect of leading-edge extensions on the aerodynamic characteristics of the model with tail off at various Mach numbers.



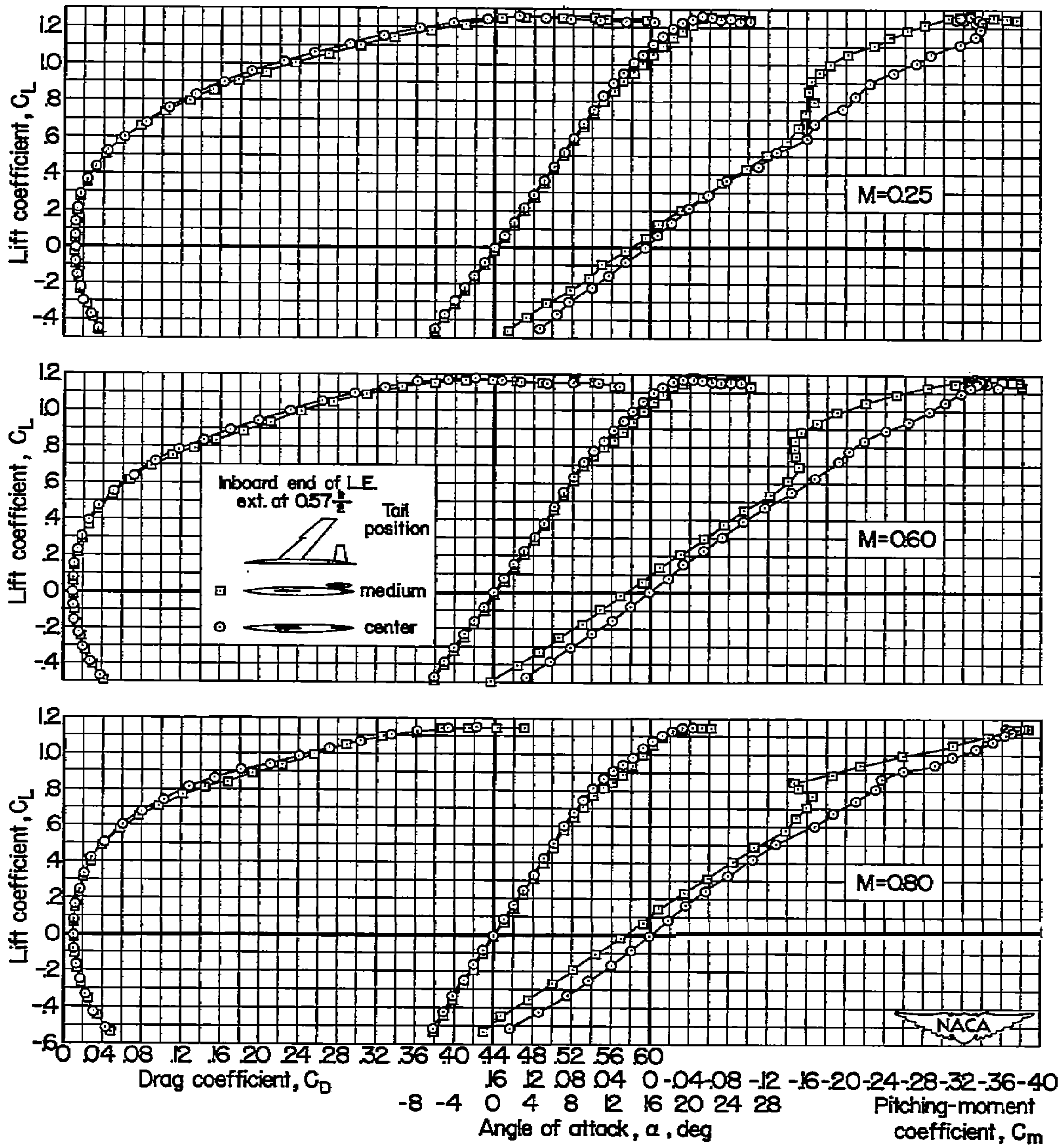
(a) M = O.=, O.@, and 0.80.

Figure 15. - me effect of tafl height on the model with a leading-e~e extension *betieen the* tip and O. ~ semi span at various Mach numbers; R = 2,~,000.



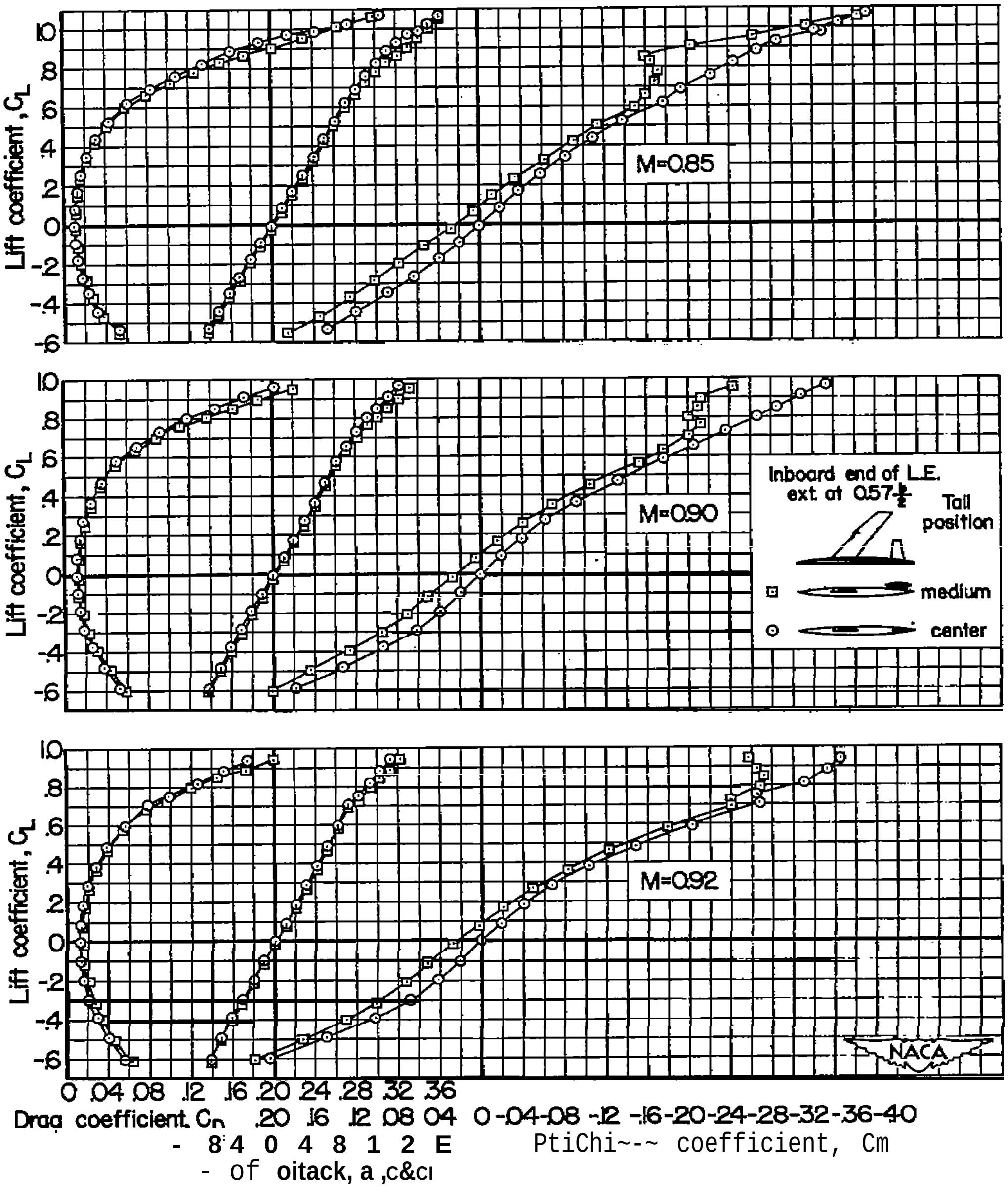
(b) M = 0.85, 0.90, and 0.92.

Figure 15. - Concluded.



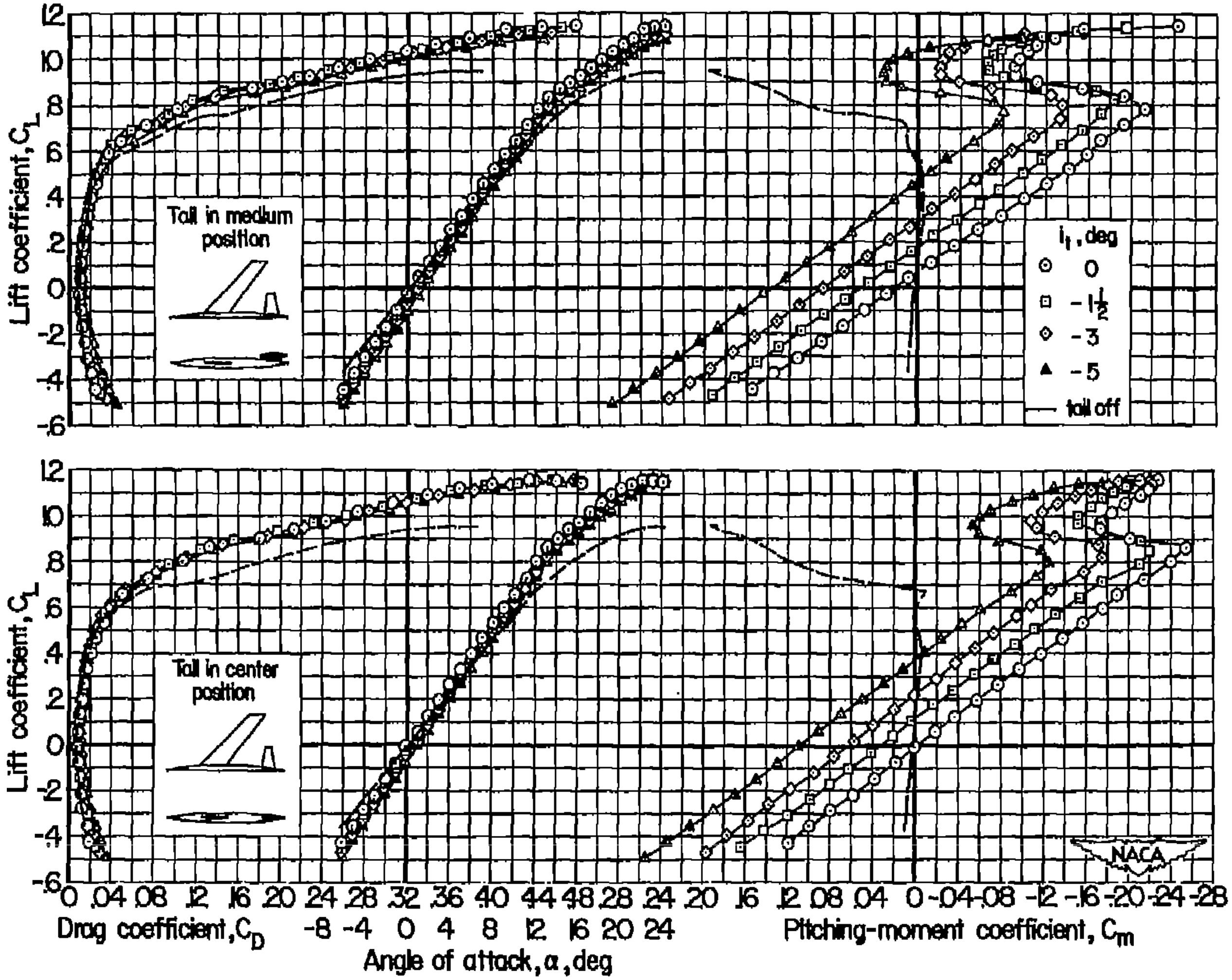
(a) M = 0.5, O.@, and 0.80.

Figure 16. - The effect of tail height on the model with a leading-edge extension between the tip and 0.57 semi span at various Mach numbers; R = 2,000,000.

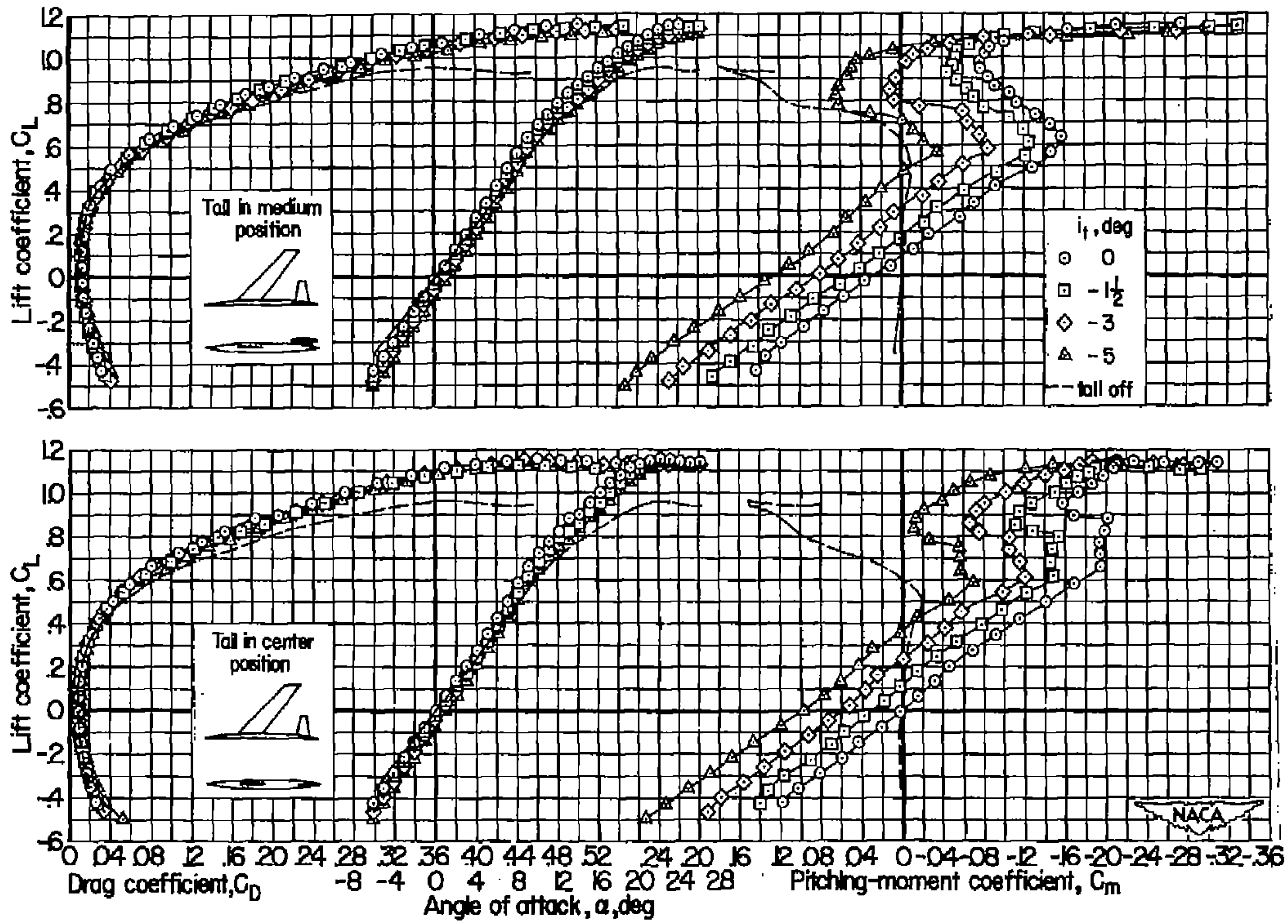


(b) M = 0.85, 0.90, and 0.92.

Figure 16. - Concluded.

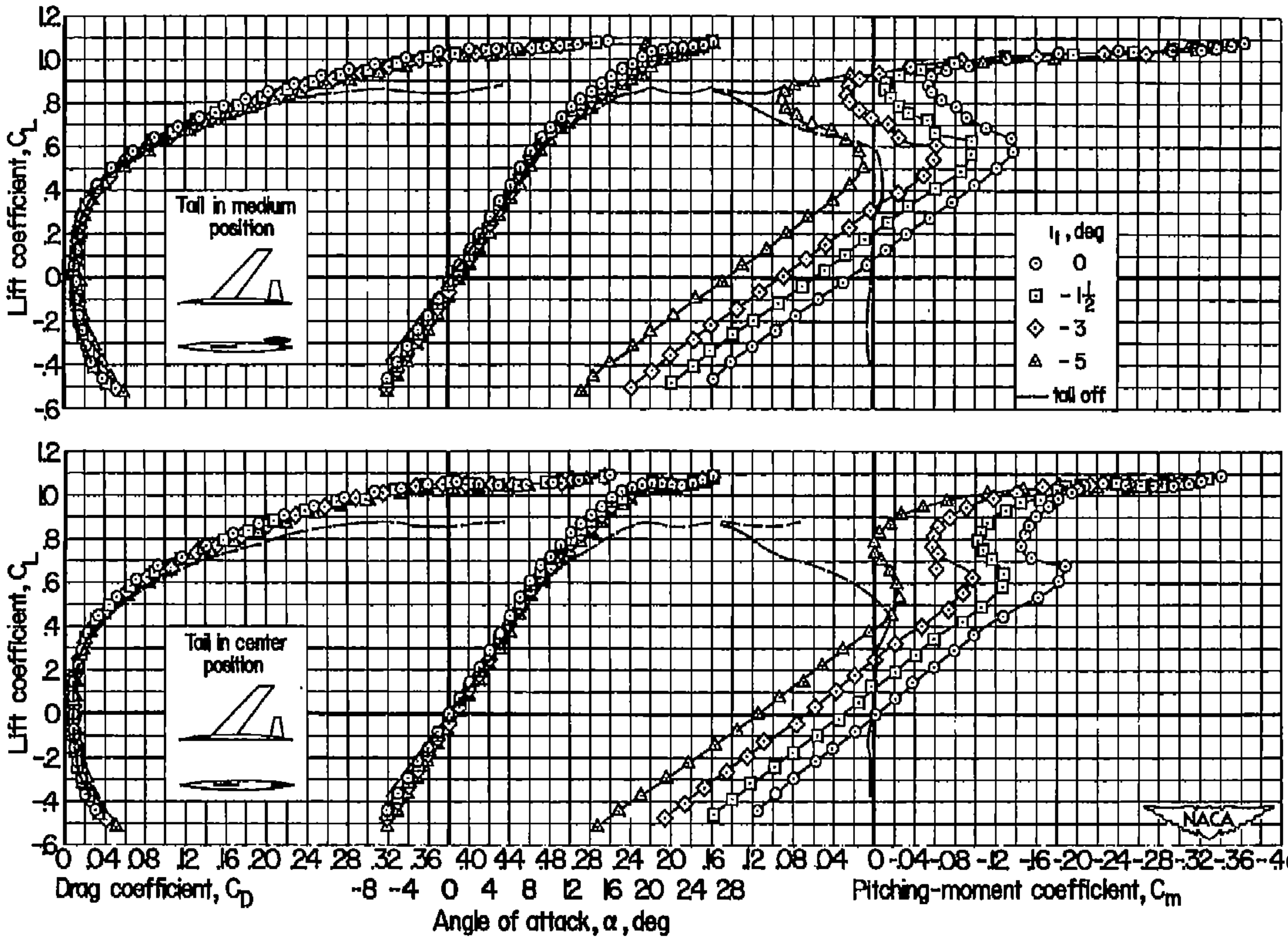


)?igure 17. - me aerodyntic chaacterlsticB of the -1 tith the tall in the medium ~d center poaltions at a ReynoldB number of K),W, W; M = O.~.



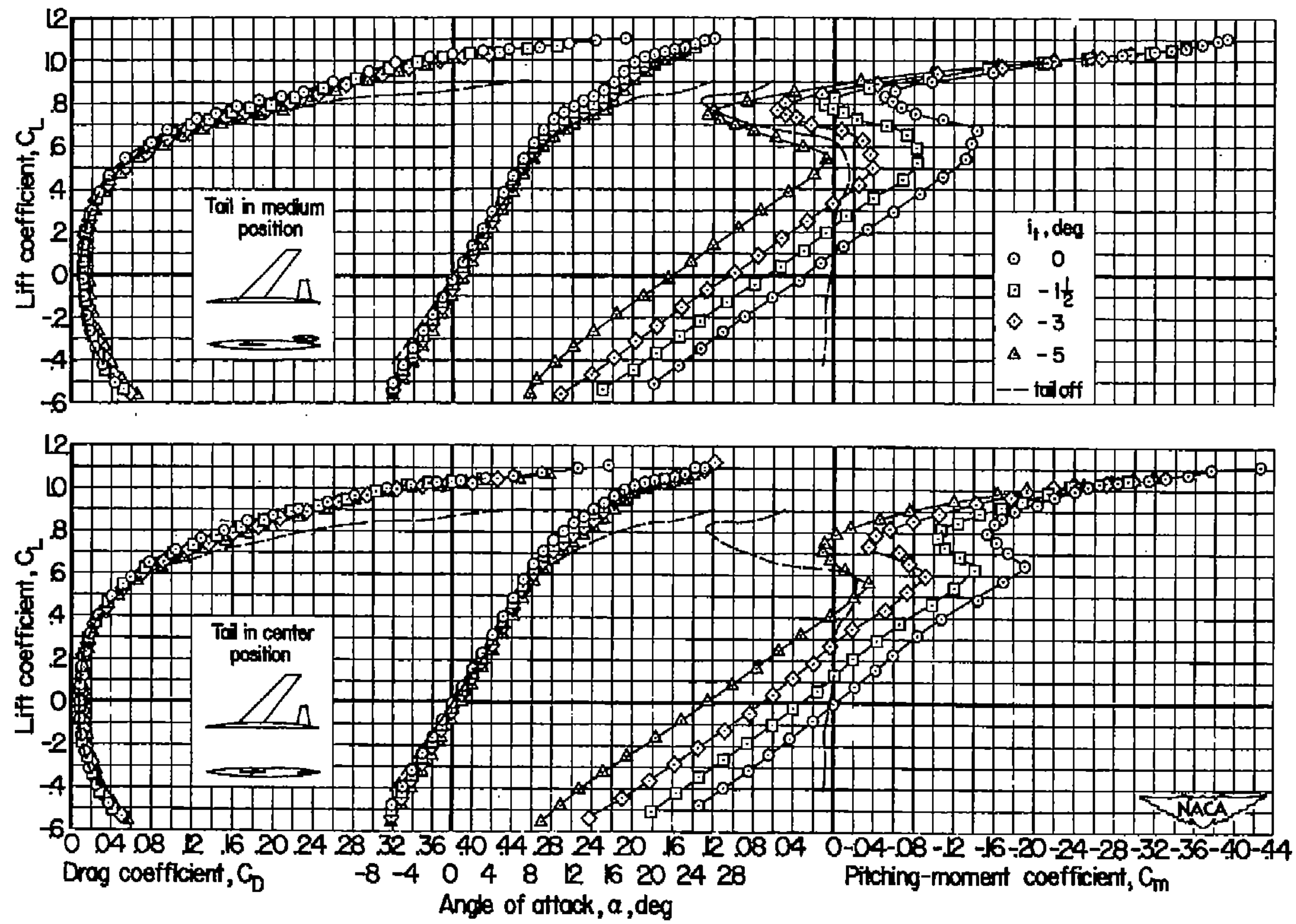
(a) M = 0.=

Fi@re 18. - The aerodynamic characteristics of the model tith the Ml in the medi~ and center ~ positlon6 at a Wynolds number of 2,000,W0.



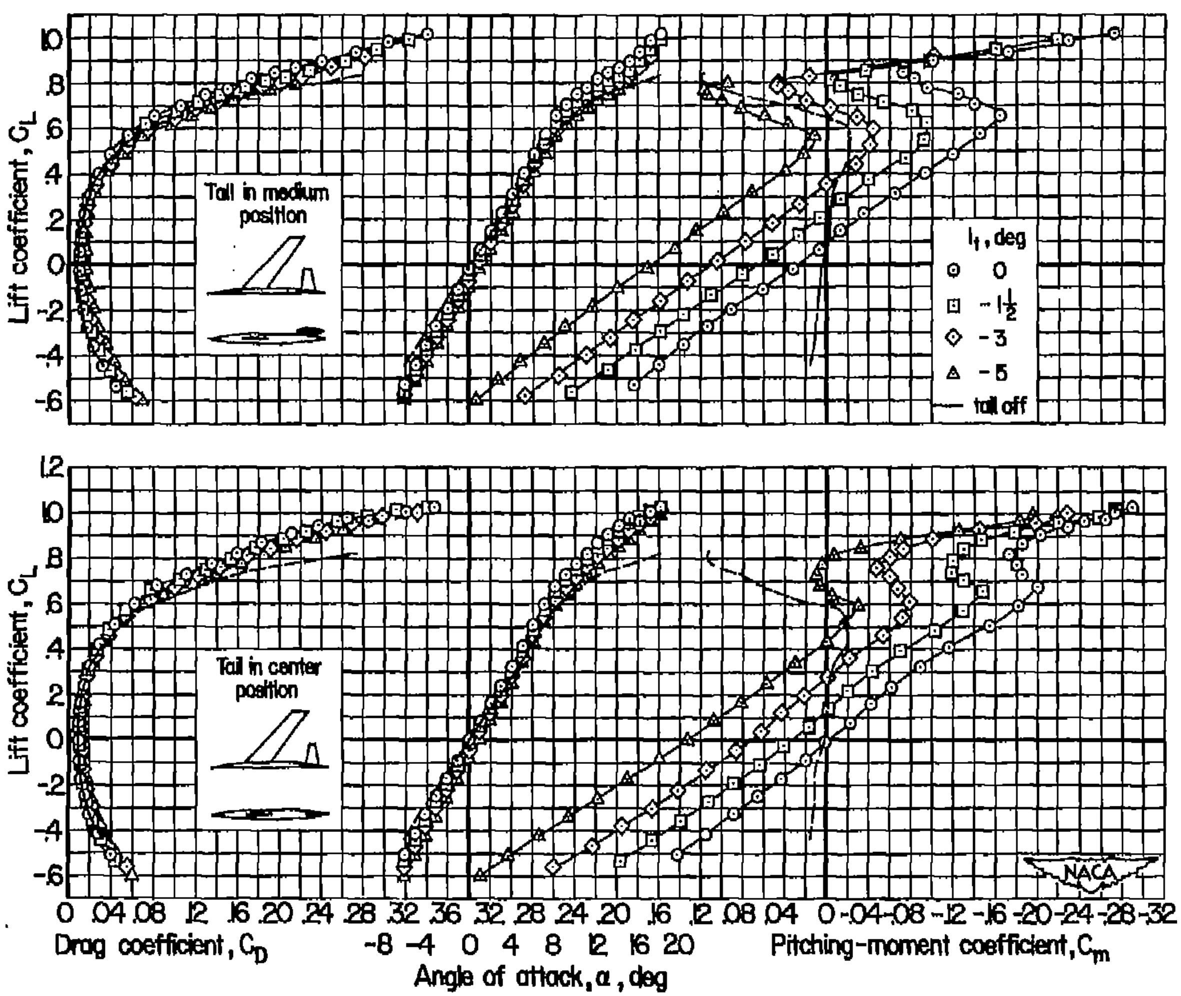
(b) M = 0.60

~l~e 18. - Continued.



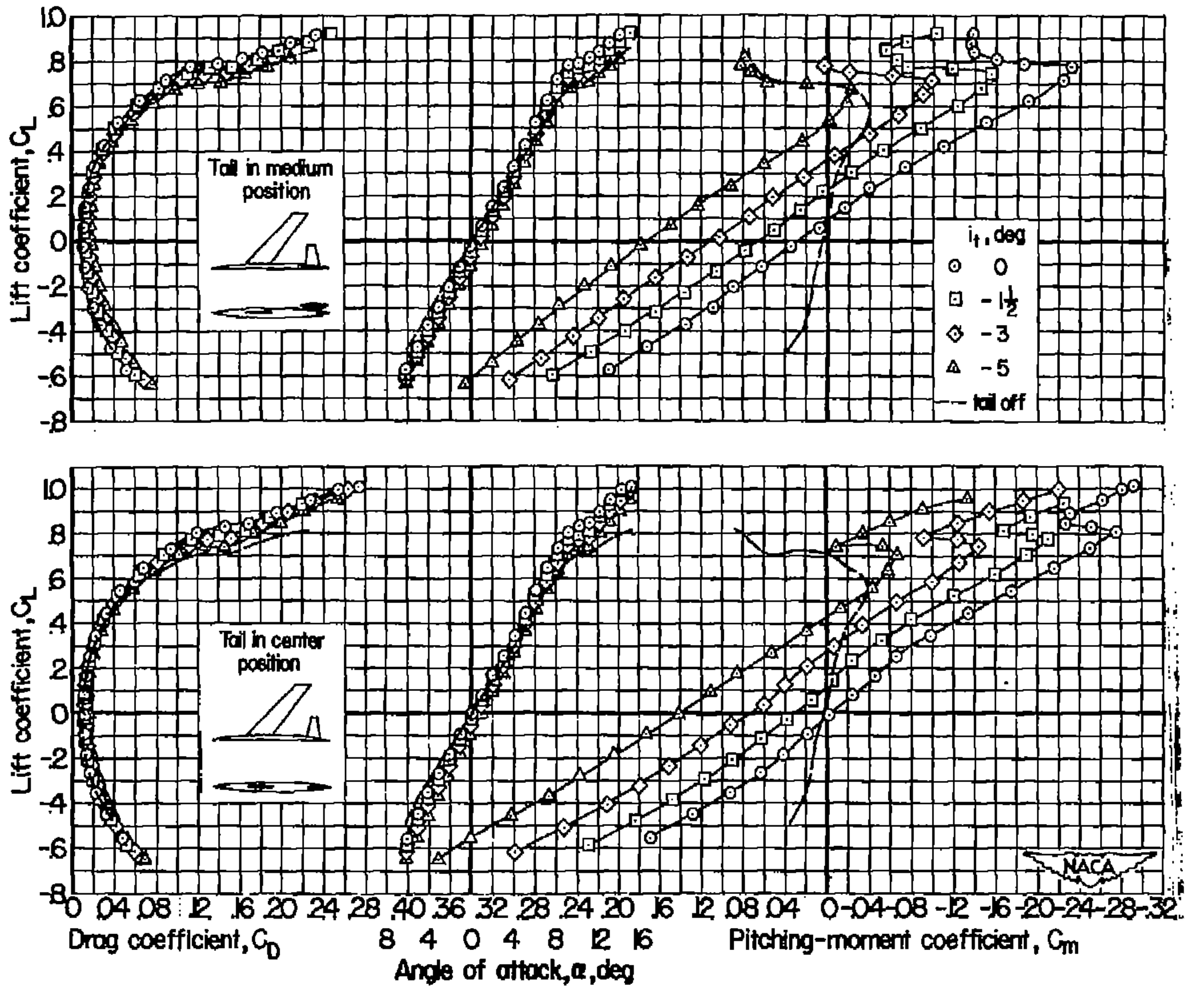
(c) M = 0.80

Figure 13. - Continued.



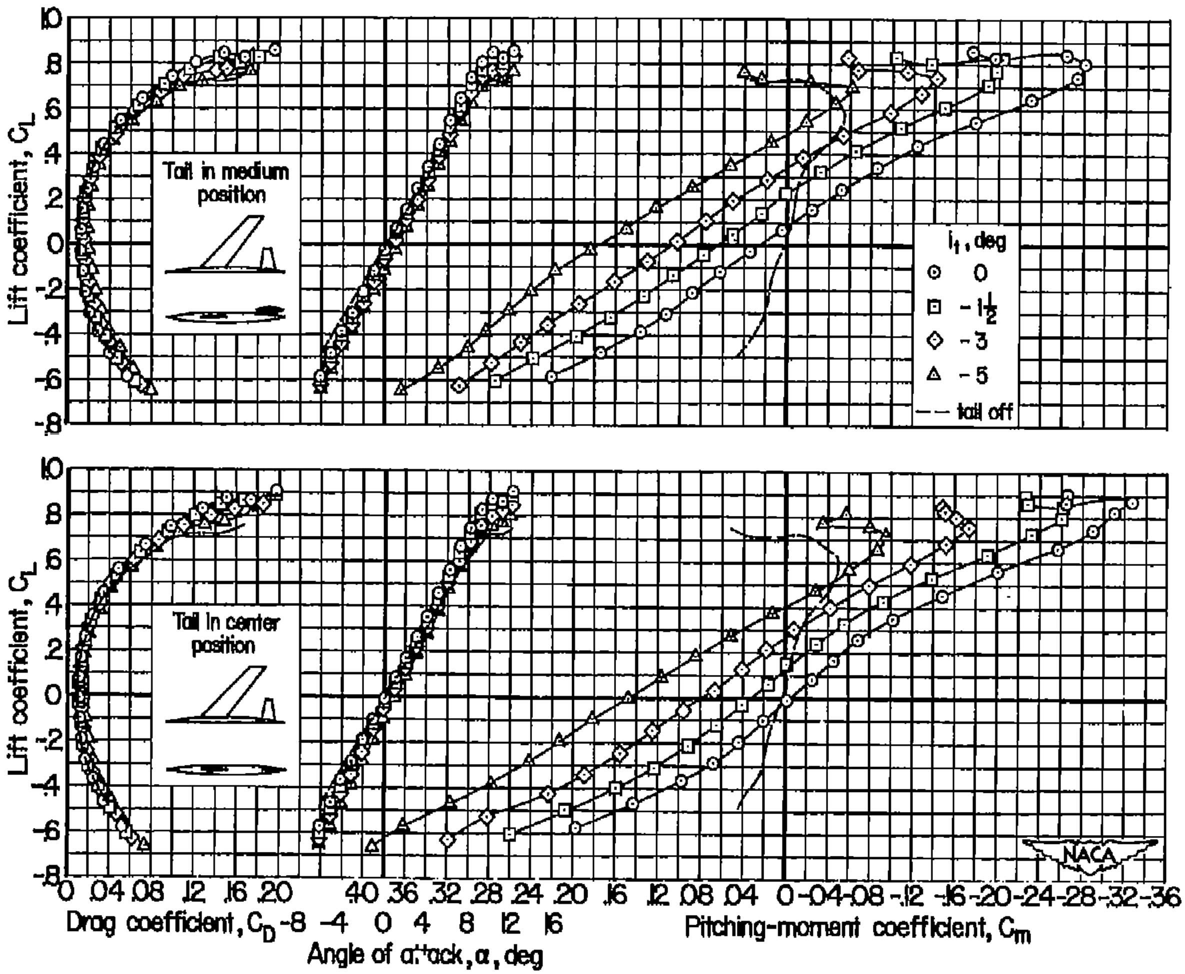
(d) M = 0.8

Figure 18. - Continued.



(e) M = 0.90

Figure 18. - Conttiued.



(f) M = 0.92

Nwe ti. - Concltied.

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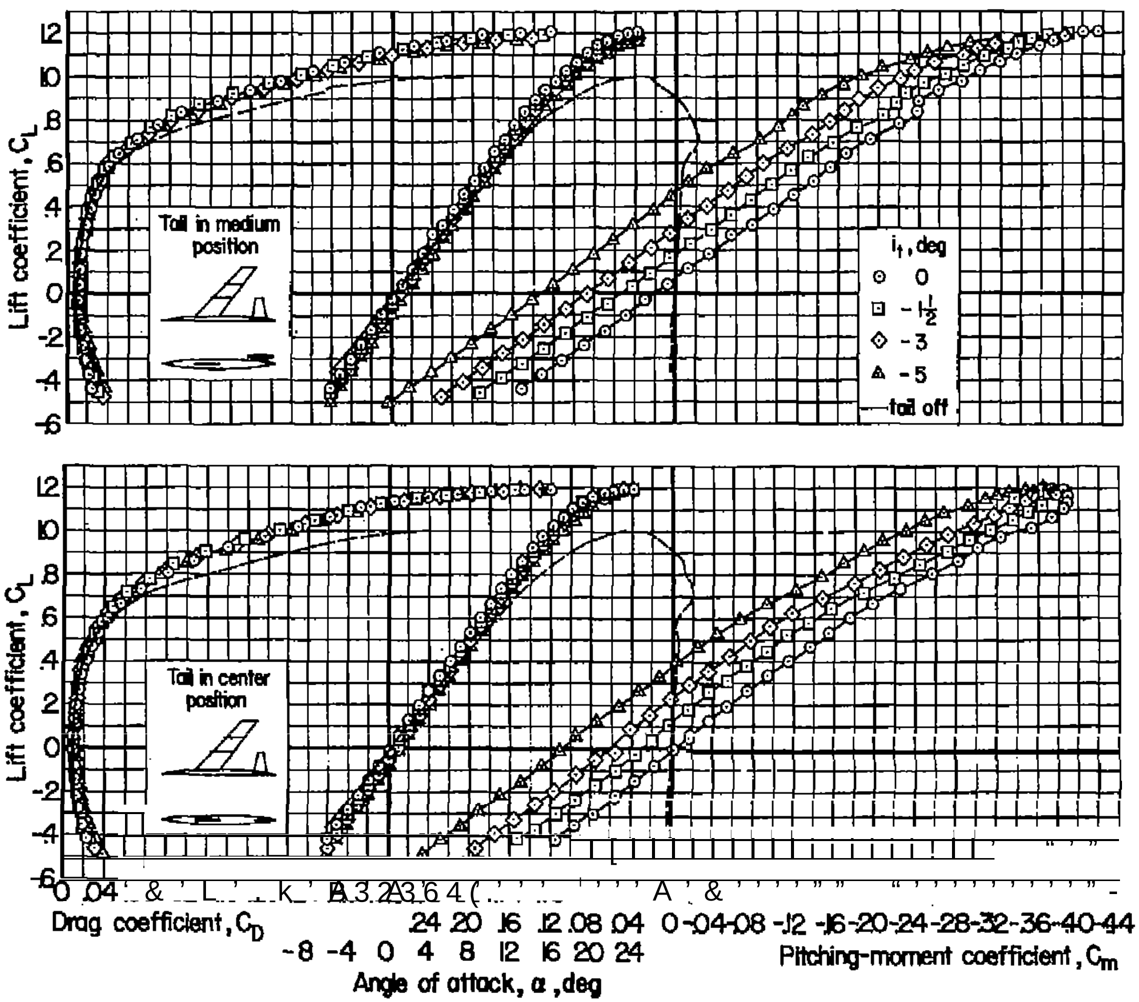

Rgure 19. - The aerodynamic charackristics of the model with fences ~a the tail in the medium and center po~itione at a Reynold8 number of 10,000,00Q; H = 0.s,

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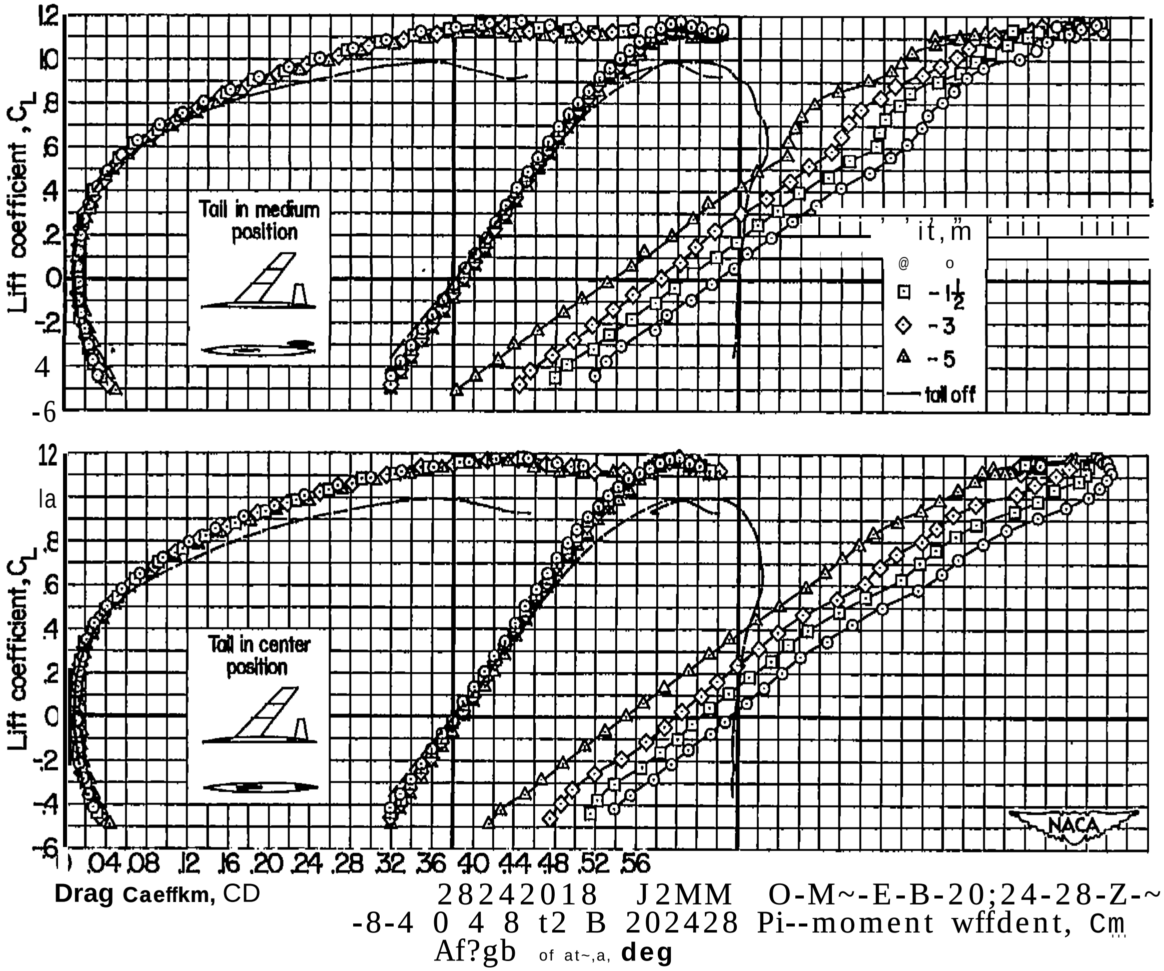
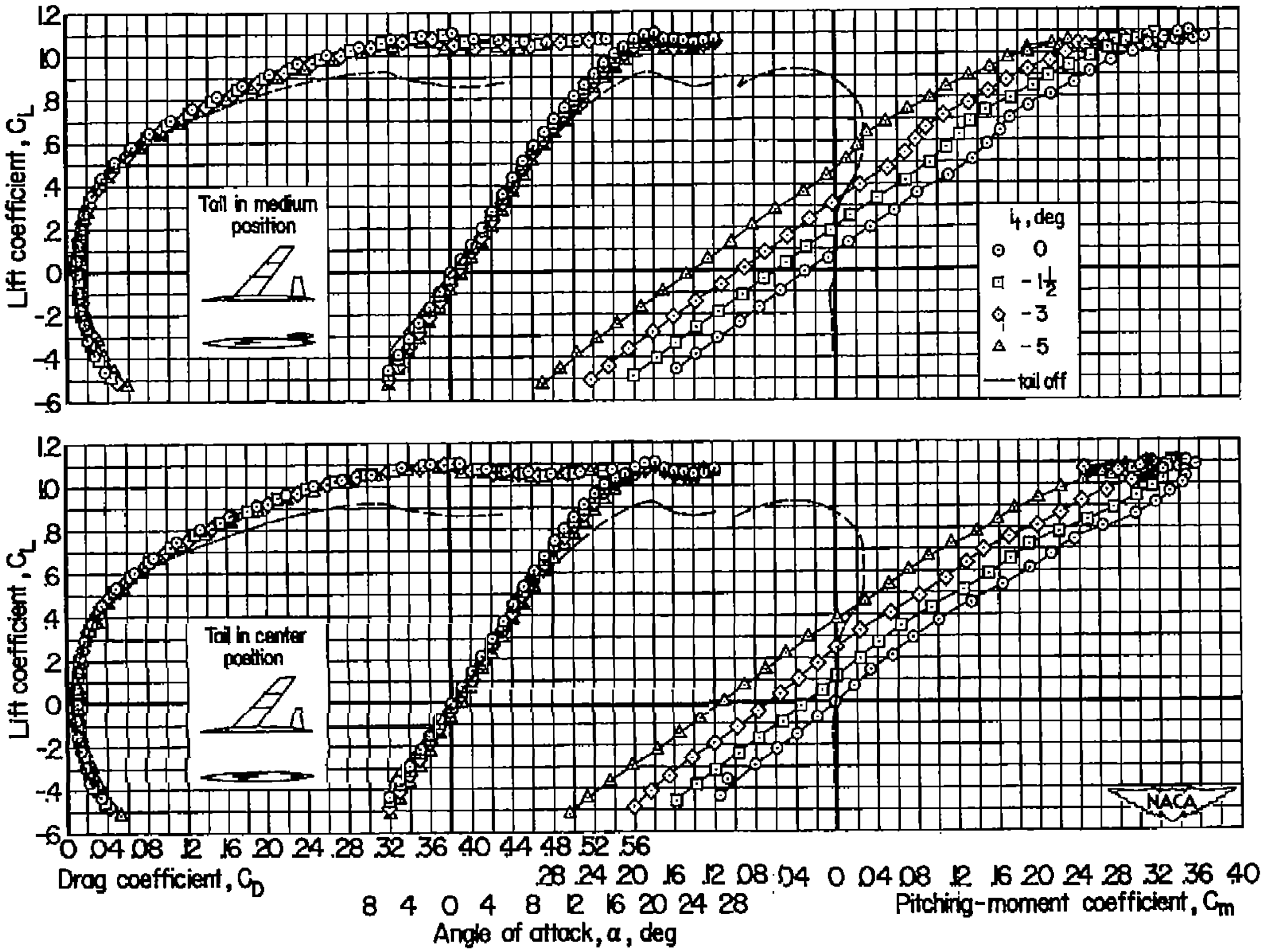


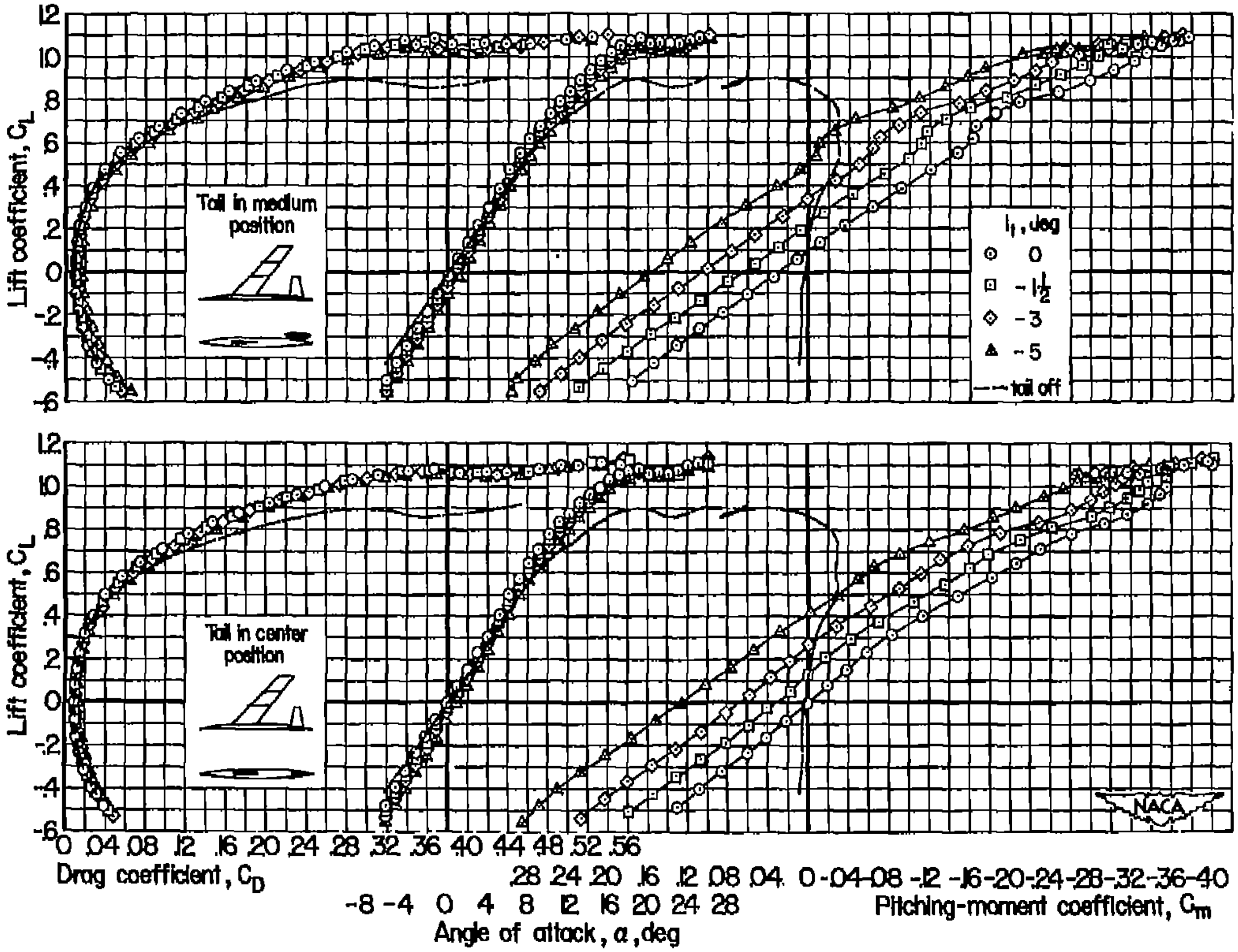
(a) M = O.~

Figure 20. - The aerodynamic characteristics of the model tith fences and the tail in the medium and center positions at a Reynolds number of 2,000,0m,



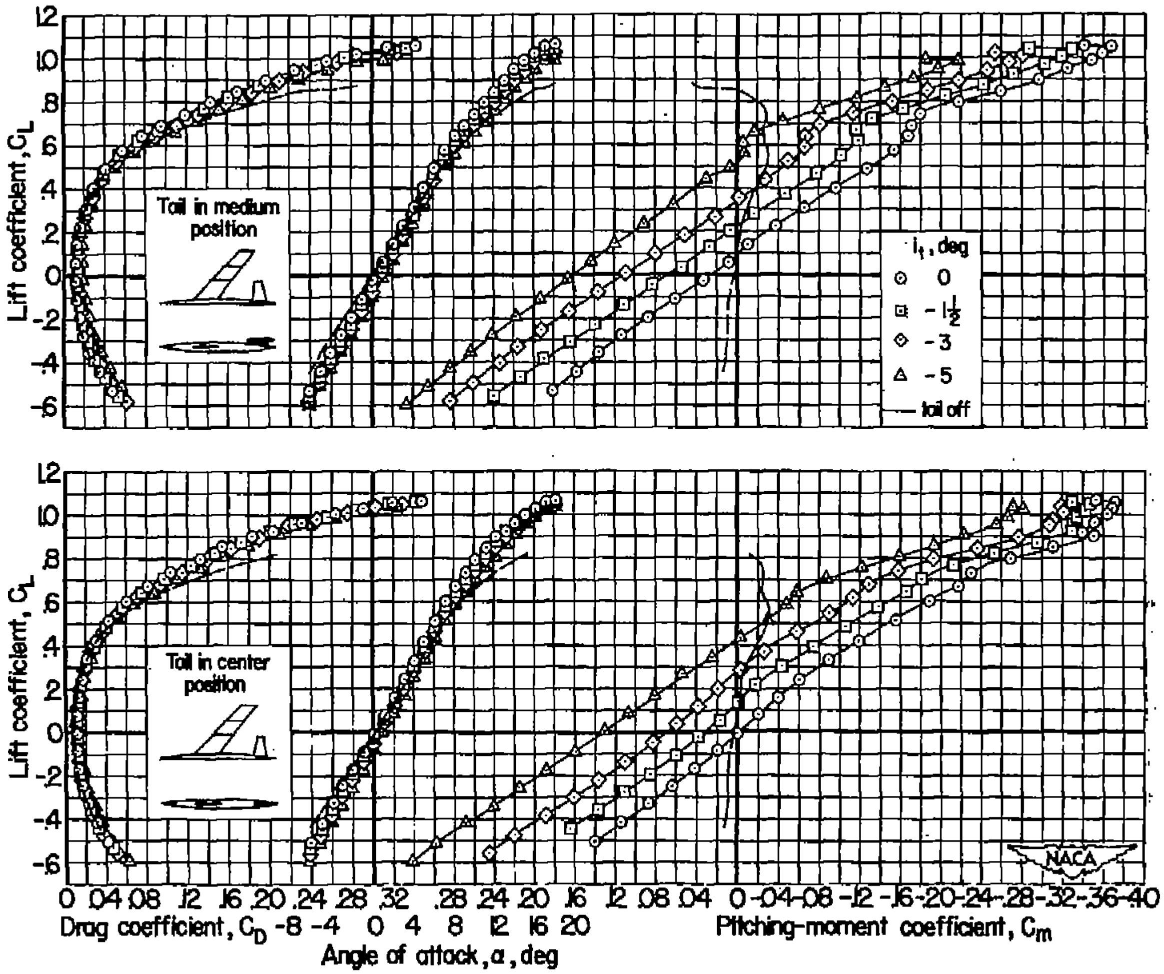
(b) M = O.&

Figure ~.- Continued.



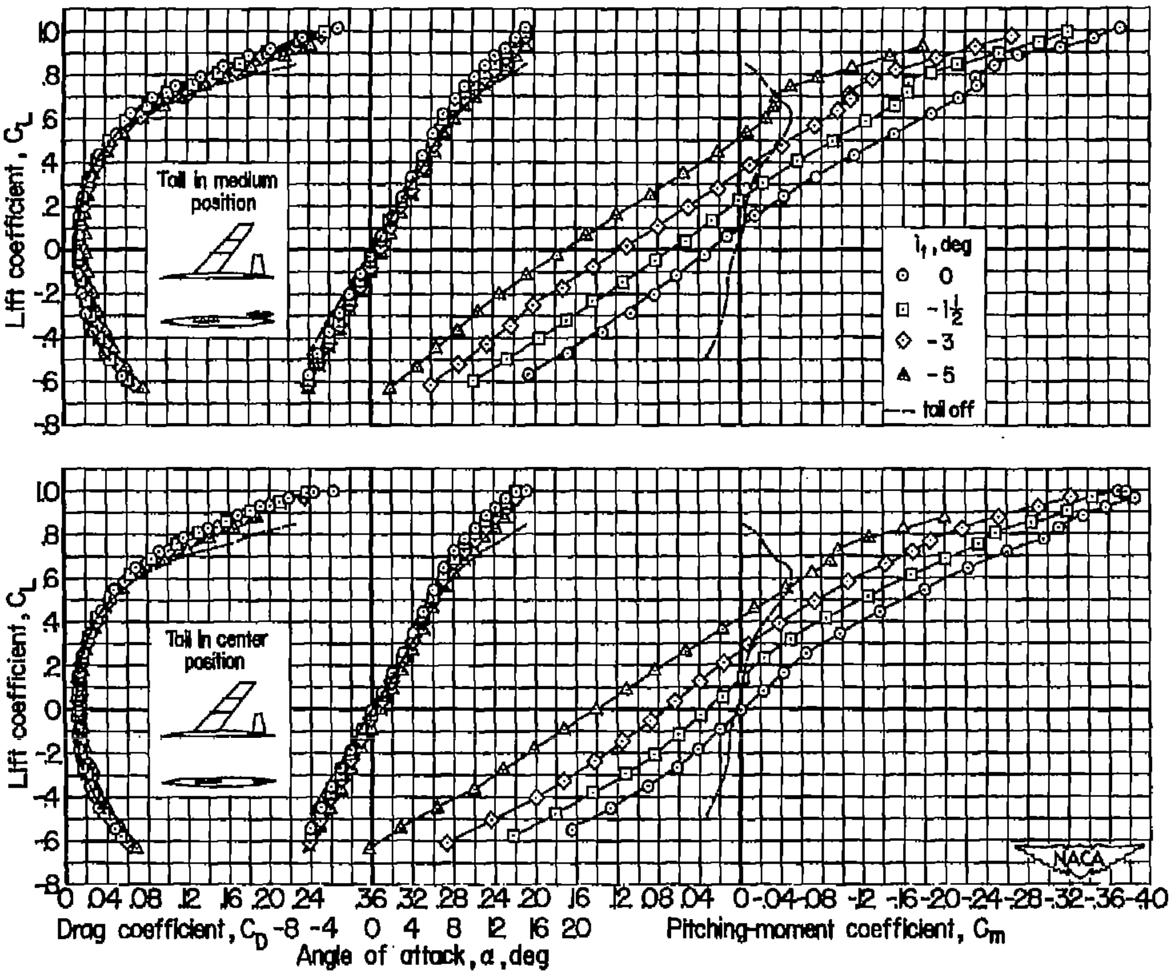
(c) M = 0.80

Figure 20.- Continued.



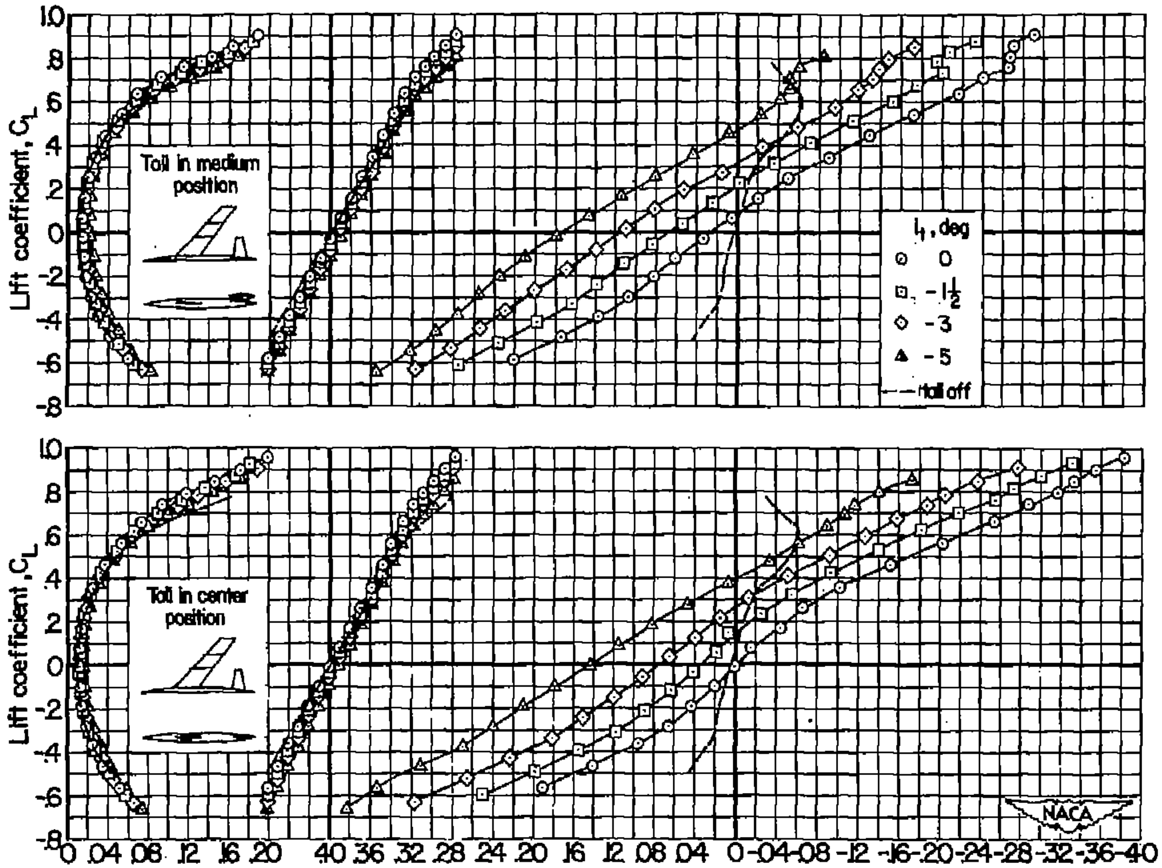
(d) M = O.@

Figure 20. - Contj.nued.



(e) M = 0.90

Figure 20. - Conttiued.



~*ci9nt,~S-4 O 4 8 t2 -rent mfftit ,C_m
@ dti,a,tig

(f) M = O.%

FiP ~.- Concluded.

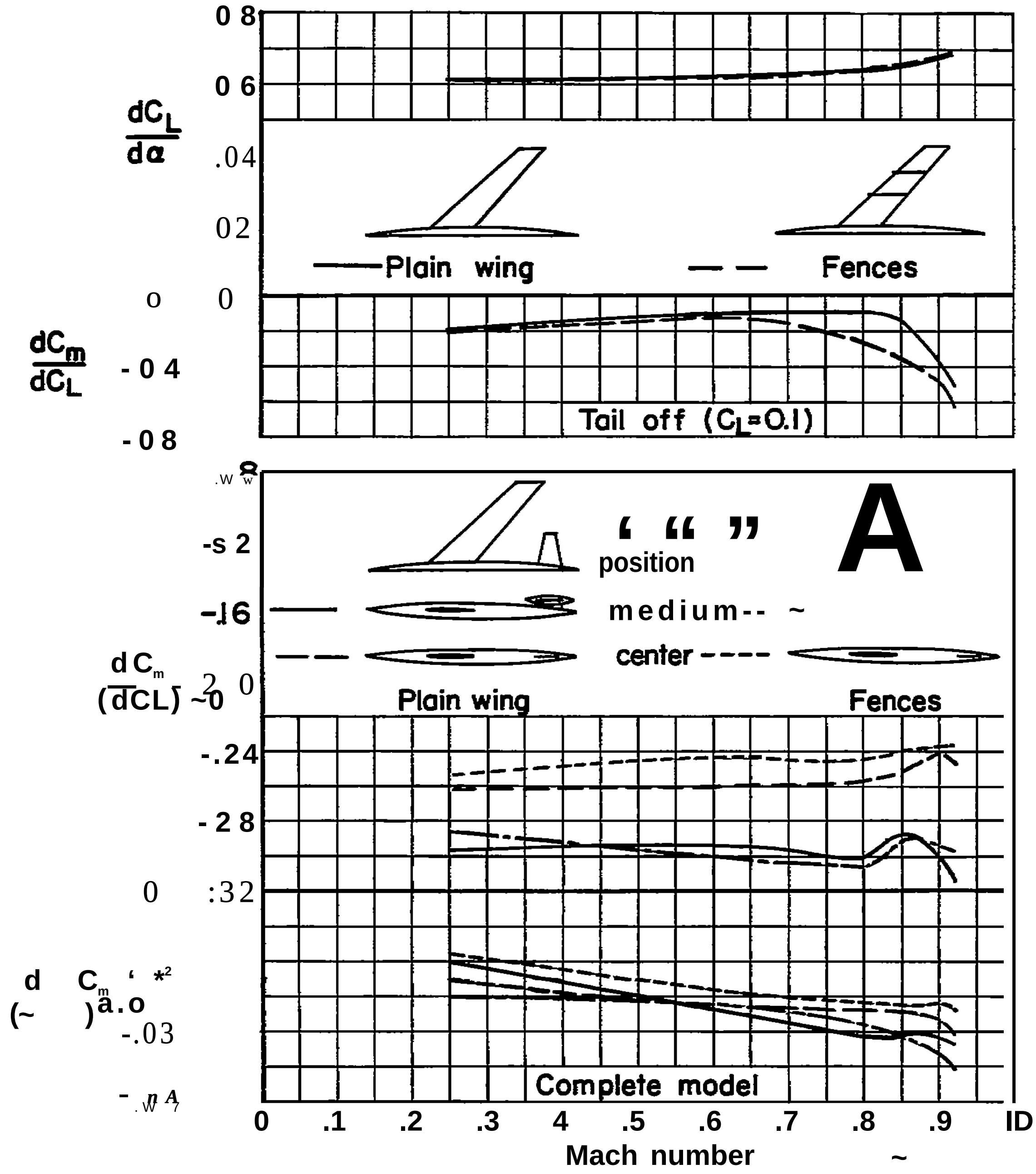
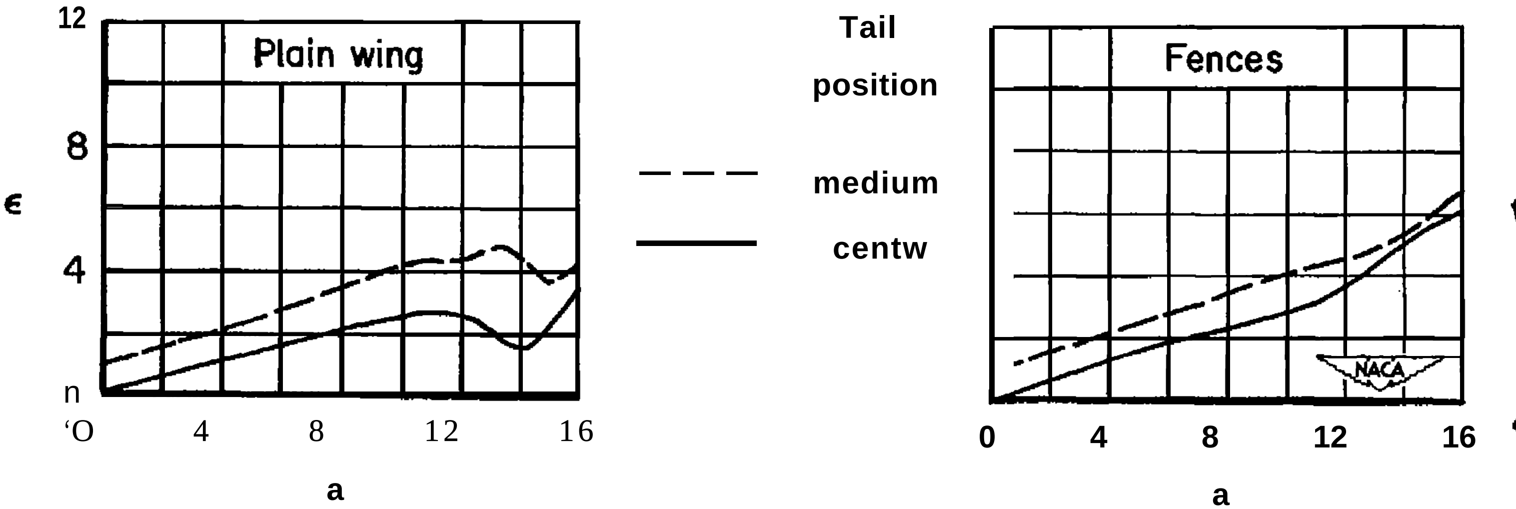


Figure 21. - The variation with Mach number of lift-curve slope, pitching-moment-curve slope, ad stabi~zer effectiveness; R = 2,~,000.



Fi~re 22. - me VFbXlatiOn Of effective d~wash at tie t~l w~~ -e of a~~k for the ~&l ~th and tithout fences at a Reynolds number of 10,~,000; M = O.~.

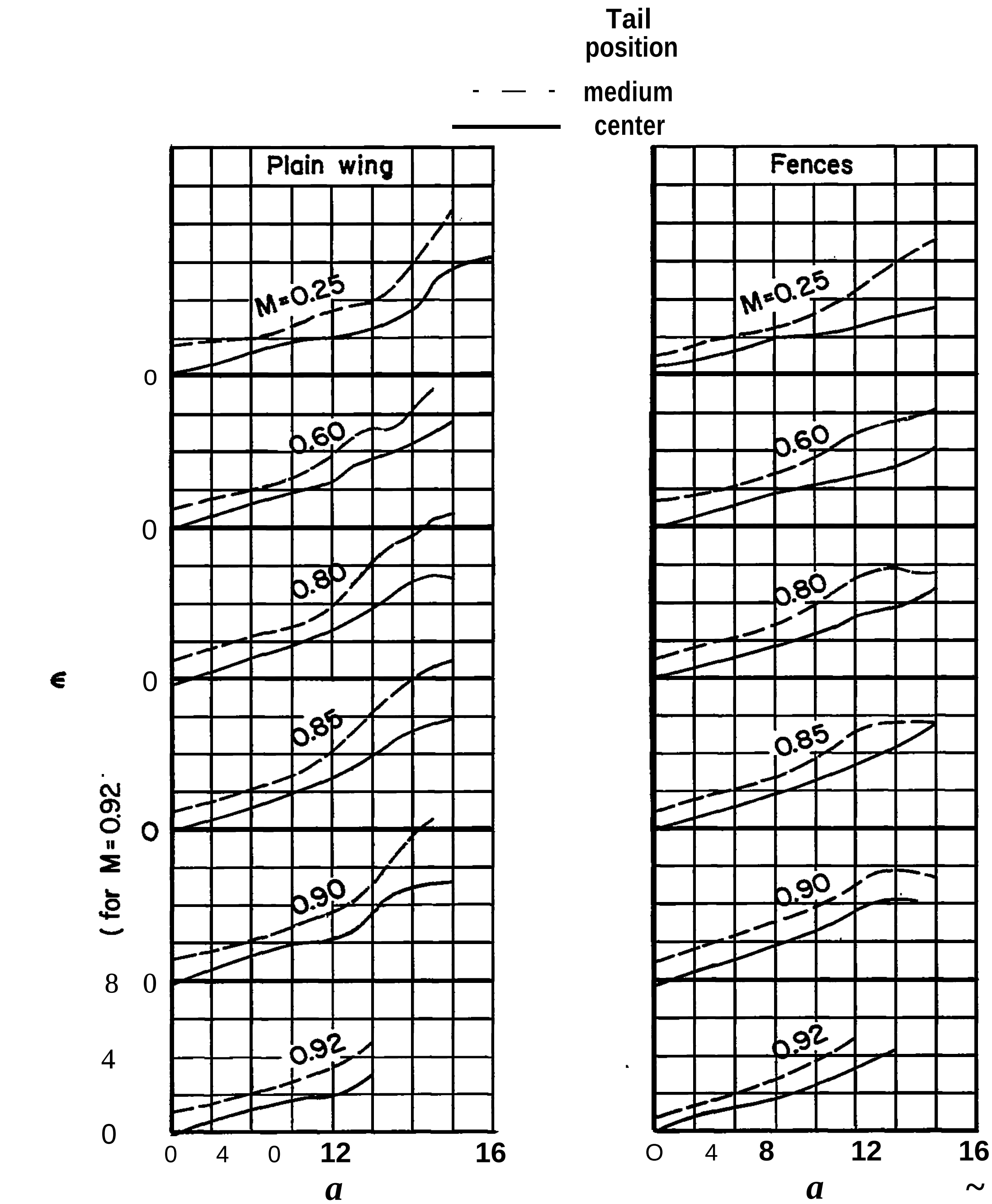


Figure 23. - The variation of effective downwash at the tail with angle of attack for the model tith and without fences at various Mach numbers; R = 2,000,~0.

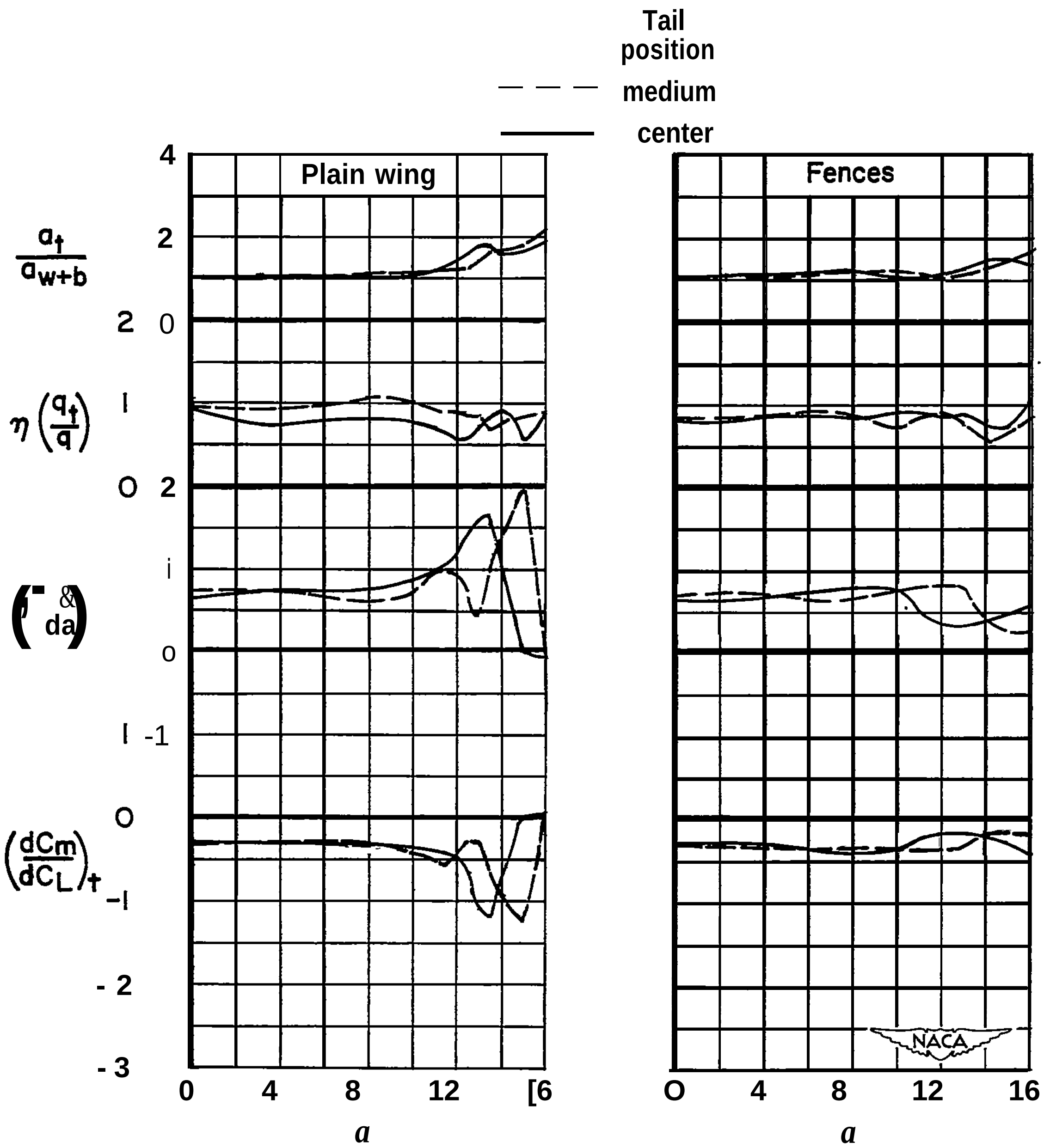
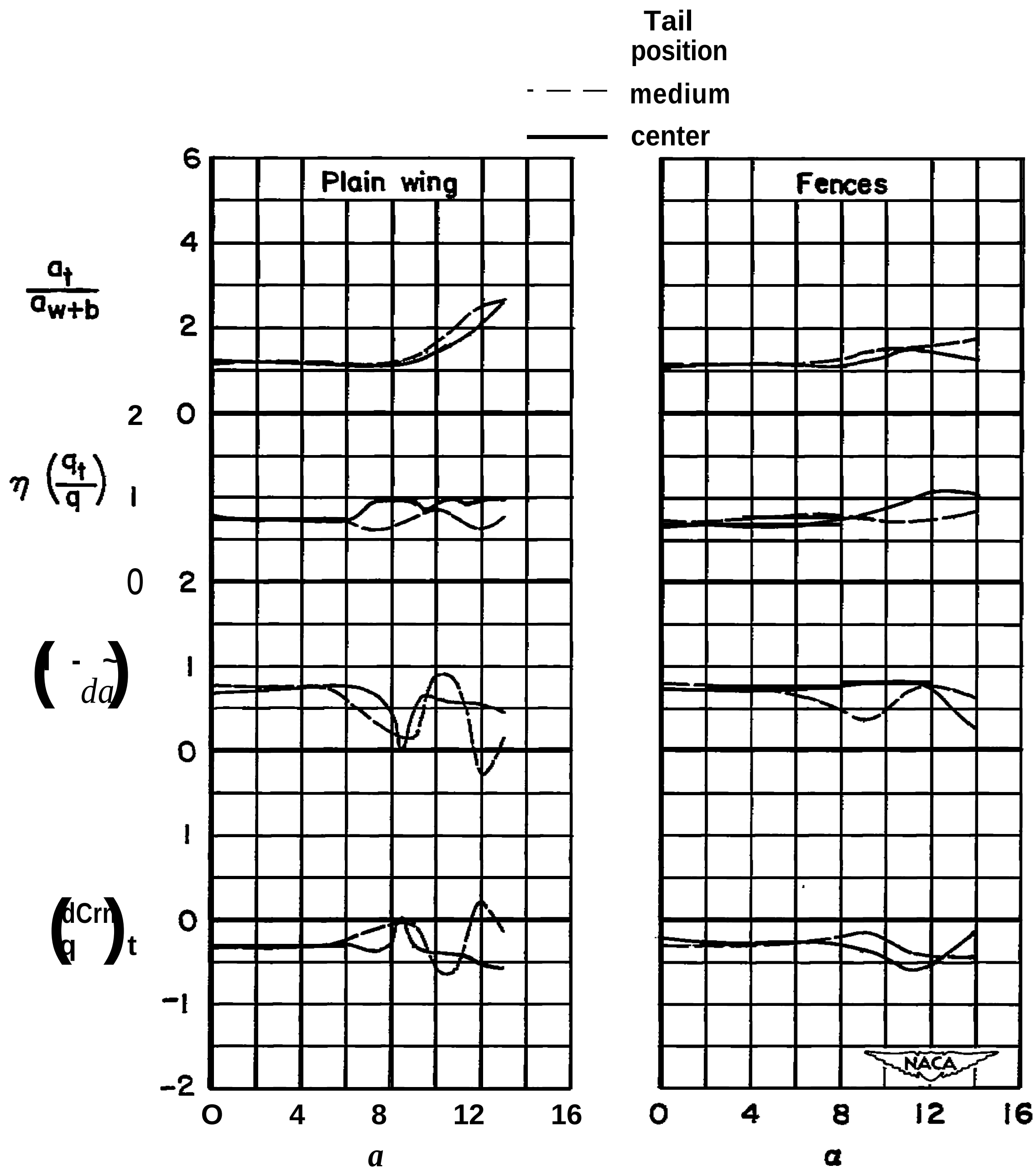
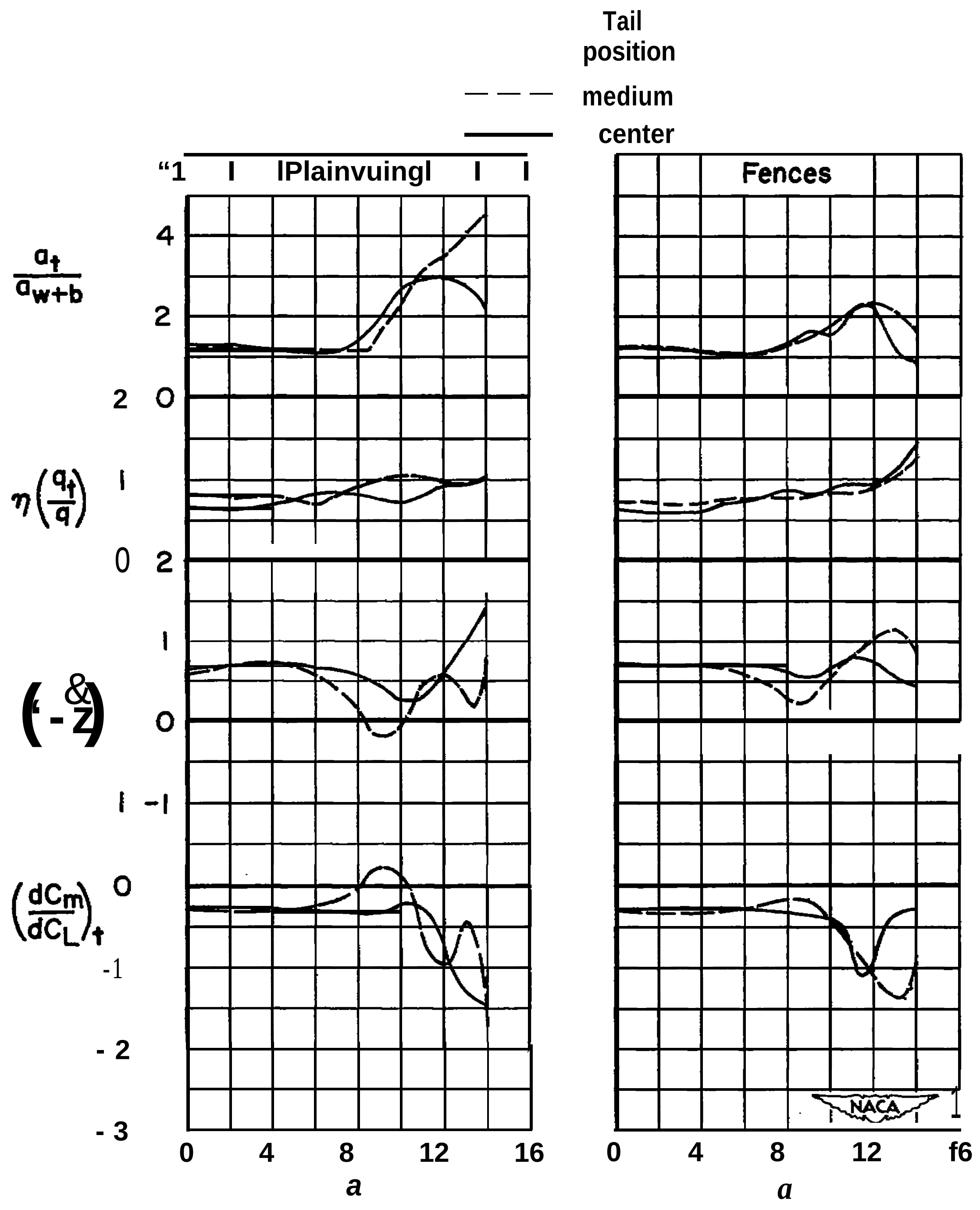


Figure 24. - The variation with angle of attack of the tail stability parameter and the factors affecting the stability contribution of the horizontal tail at a Reynolds number of 10,000,000; M = 0.25.



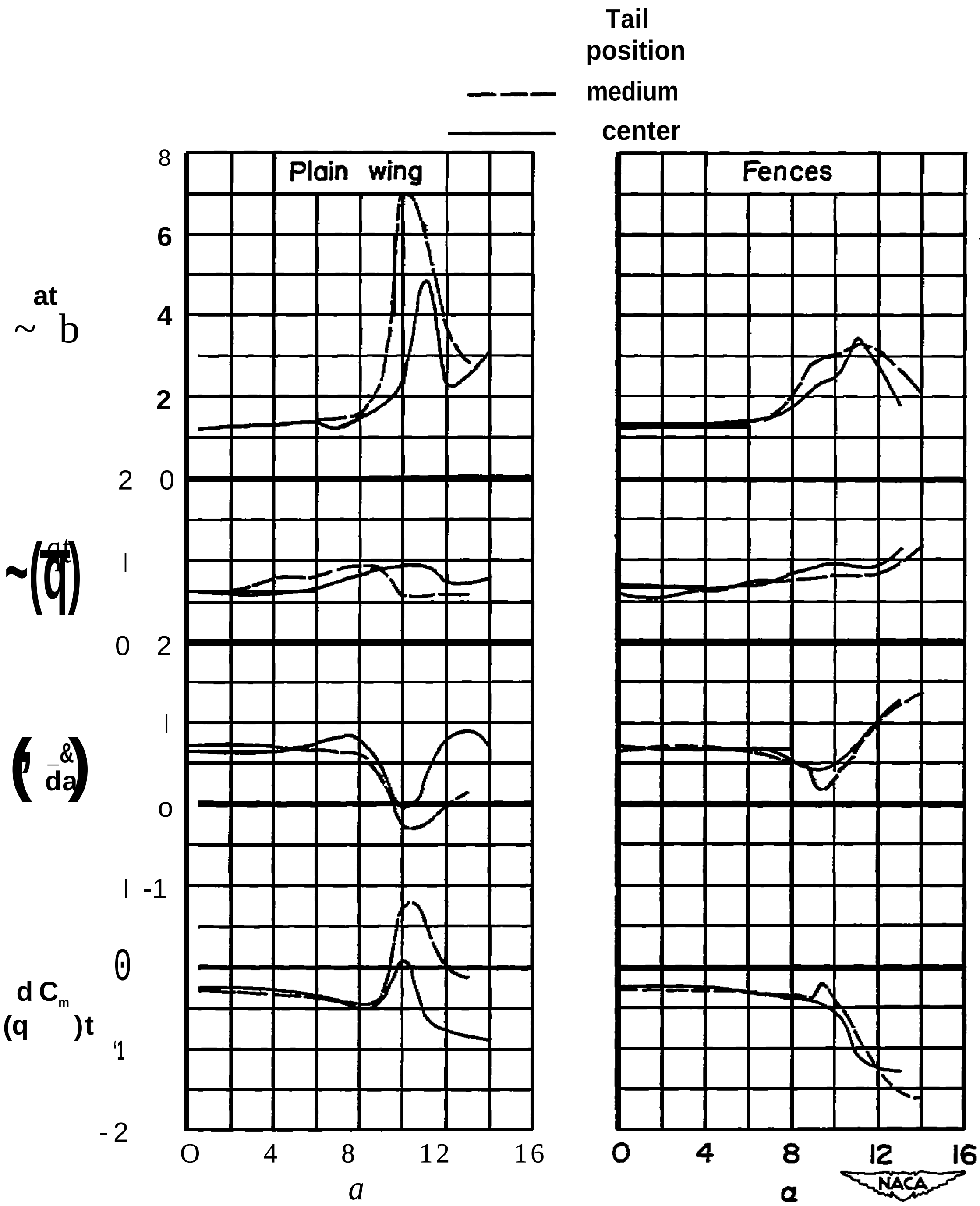
(a) M = 0.60

Figure ~. - me vafiation with angle of attack of the tail stability parmeter and the factors affecting the stability contribution of the horizontal tail; R = 2,000,000.



(b) M = 0.80

Figure ~. - Continued.



(c) M = 0.~

Fi&e ~. - Concluded.

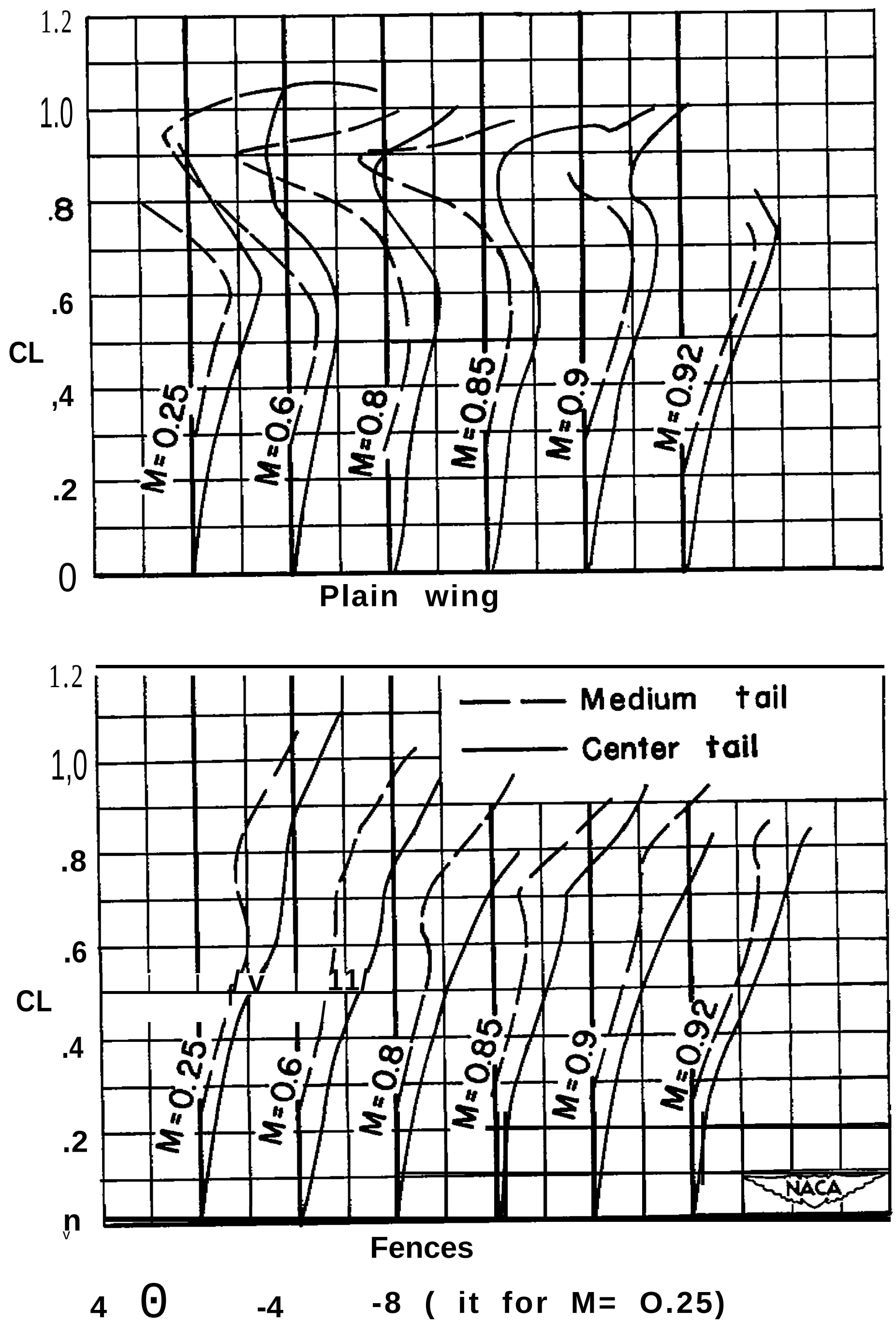


Figure 26.- The variation of tail incidence for longitudinal balance with lift coefficient at various Mach numbers; c.g. at 0.4$\bar{c}$, R = 2,000,000.